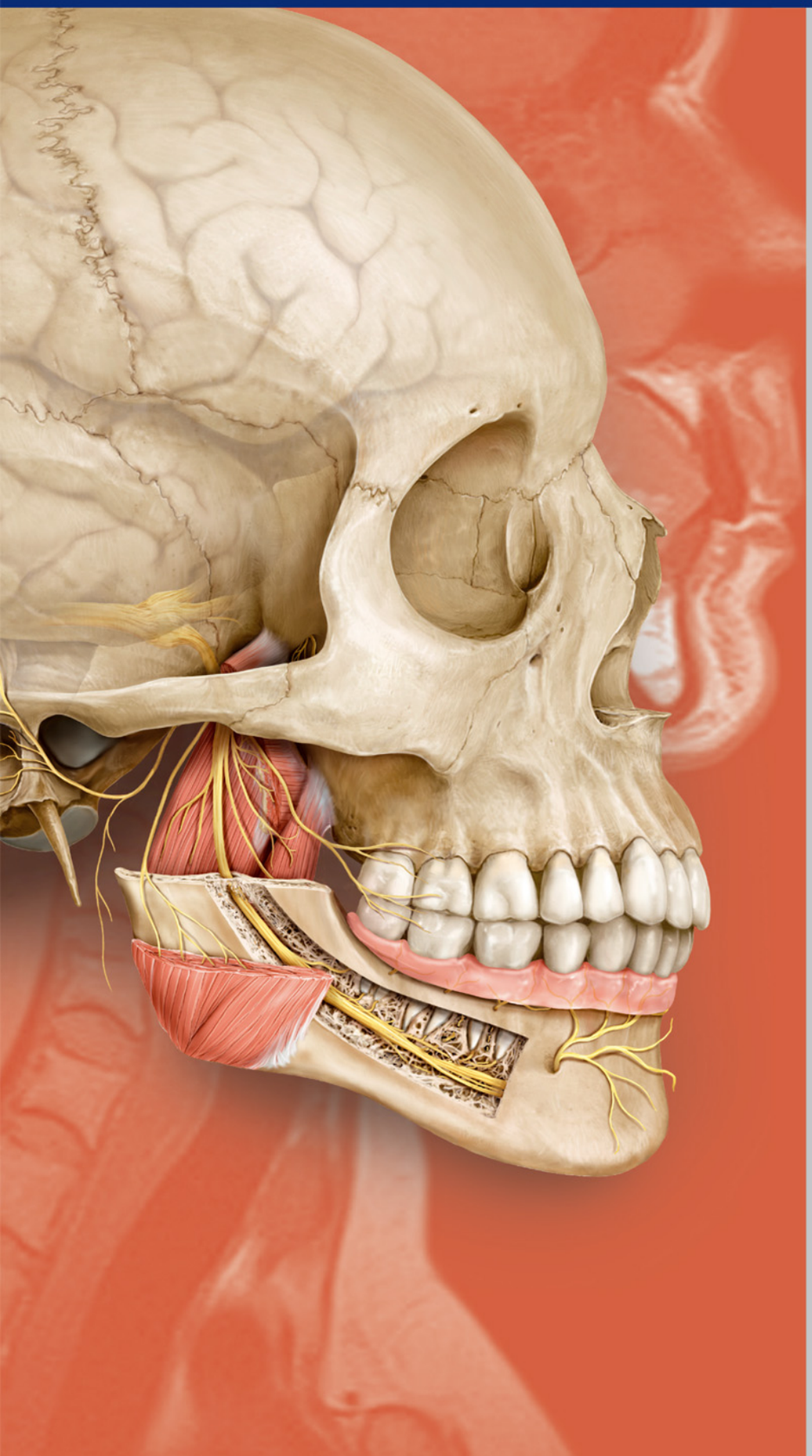
Anatomy for Dental Medicine

Latin Nomenclature



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Anatomy for Dental Medicine

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To my wonderful wife, Amy Curran Baker,
and my awe-inspiring daughters, Phoebe and Claire

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Preface to the Second English Edition

Before embarking on the second edition of *Anatomy for Dental Medicine*, we sought to find out how anatomy is currently being taught in North America. We consulted members of the American Dental Education Association (ADEA) and read their Basic Science Survey Series for Dentistry, a series of reports that clarify this very issue. What we found out is that teaching time is being squeezed and many institutions have combined courses that were once stand-alone (e.g., embryology, histology, and neuroanatomy) into the anatomy course. Armed with this knowledge, we set out to create a single-volume text atlas that would cover dental student's needs across all formats of anatomy education, a feat that we think we have achieved with this second edition.

Some key features retained from the first edition are:

- Organized in a user-friendly format in which each two-page spread is a self contained guide to a specific topic.
- Intuitively arranged to facilitate learning. Coverage of each region begins by discussing the bones and joints and then adds the muscles, the vasculature, and the nerves. This information is then integrated in the topographic neurovascular anatomy coverage that follows.
- Features large, full-color, highly detailed artwork with clear and thorough labeling and descriptive captions, plus numerous schematics to elucidate concepts and tables to summarize key information for review and reference.
- Includes a full chapter devoted to sectional anatomy with radiographic images to demonstrate anatomy as seen in the clinical setting.

The second edition has two new chapters: an embryology chapter that introduces dental students to all of the major concepts that they need to be familiar with and that puts anatomical concepts from later chapters in context, and a chapter that covers the anatomy of the rest of body, which includes coverage of the upper limb, thorax, abdomen, and pelvis (the back is covered in Chapter 11 with the neck). In addition, we increased our coverage of neuroanatomy such that it should be sufficient to meet dental student's needs.

In this second edition, we also rearranged material into a more regional approach, thus enhancing its usefulness as a companion to lecture-based material and to dissection courses. However, we also retained a systemic anatomy approach at the beginning of the atlas, which allows certain topics to be presented more clearly while providing a good entry point for the novice learner.

Other notable changes to the second edition include a new appendix on the anatomy of dental local anesthesia, which is one of the critical applications of head and neck anatomy. There are also appendices that include factual-type questions to test recall of information and clinical vignette-style questions that test comprehension and application. These appendices include full answer explanations. There is also more than 400 new illustrations, summary tables, dentally relevant clinical correlations, radiographs, and full-color photographs. The text, artwork, and labels have been thoroughly updated, and we welcome the continuing support of those members of the medical and dental community who alert us to any issues and keep us on our toes! All in all, we have taken our very well-received first edition and given it even more relevance and appeal such that it should serve dental students—and other students for whom the head and neck holds particular relevance—well for many effective years of studying to come.

A Note on the Use of Latin Terminology

To introduce the Latin nomenclature into an English textbook is a delicate task, not least because the English language is composed of a large number of loanwords from Latin that have passed into general use. Some loanwords are so common that fluency of the text would be disturbed if they were to be translated back to Latin. The Latin loanwords have typically undergone several adaptations to the English language. A term such as *sympathetic trunk* (lat. *truncus sympaticus*) has undergone morphological adaptation (through the loss of masculine suffix *-us*), orthographical adaptation (via the substitution of a Germanic *k* for a Latin *c*), and phonological adaptation (*th* and *e* instead of *t* and *i*); further, the word order has been reversed. The Latin term *sympaticus* is in fact borrowed from late Greek *sympathetikos* (from *sympathes*: "having a fellow feeling, affected by like feelings"), illustrating that terms move between languages when cultures meet. Other anatomical terms are so colloquial (e.g., *hand*), that a Latin term (e.g., *manus*) would be inappropriate to use at all occasions. Hence, the text would easily become unreadable if full stringency of the translation would be applied. Regarding figures and tables, Latin has been used whenever possible, and in the text body Latin has been used unless it would considerably disturb the fluency. In some cases, dual terminology has been used and the English term or the Latin term has been put in parenthesis. As much as possible, the terminology of *Terminologia Anatomica* (1998) has been followed.

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Eric W. Baker

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Finally, I would like to dedicate my work with this edition to the autopsy technician Lars Winblad, who unexpectedly passed away at a too early age.

Hugo Zeberg

Acknowledgments from the First English Edition

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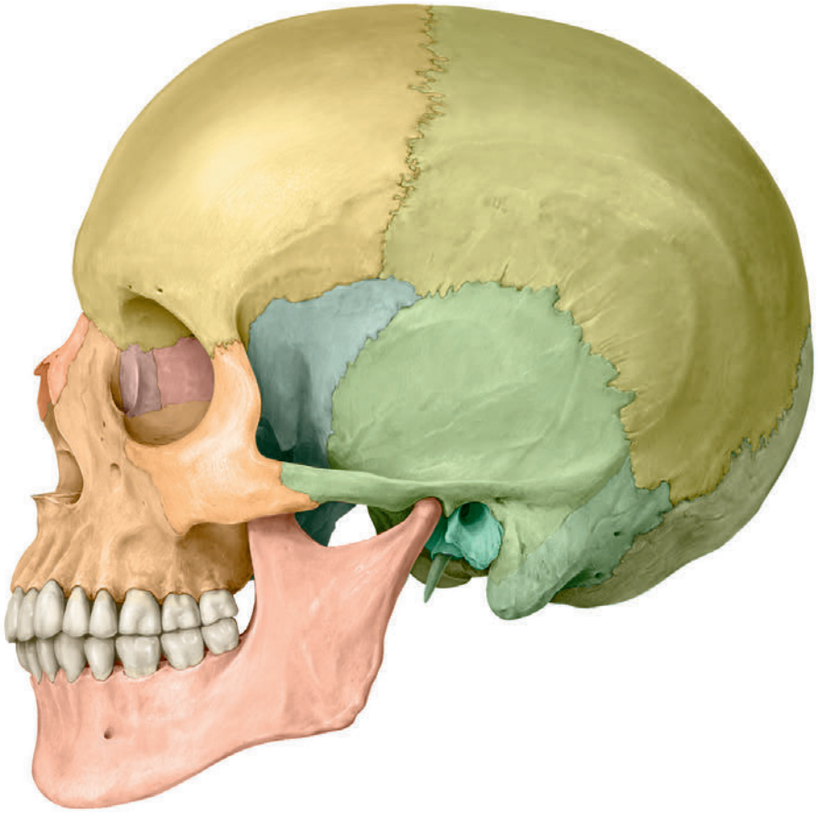
Eric W. Baker



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Germ Layers & the Developing Embryo

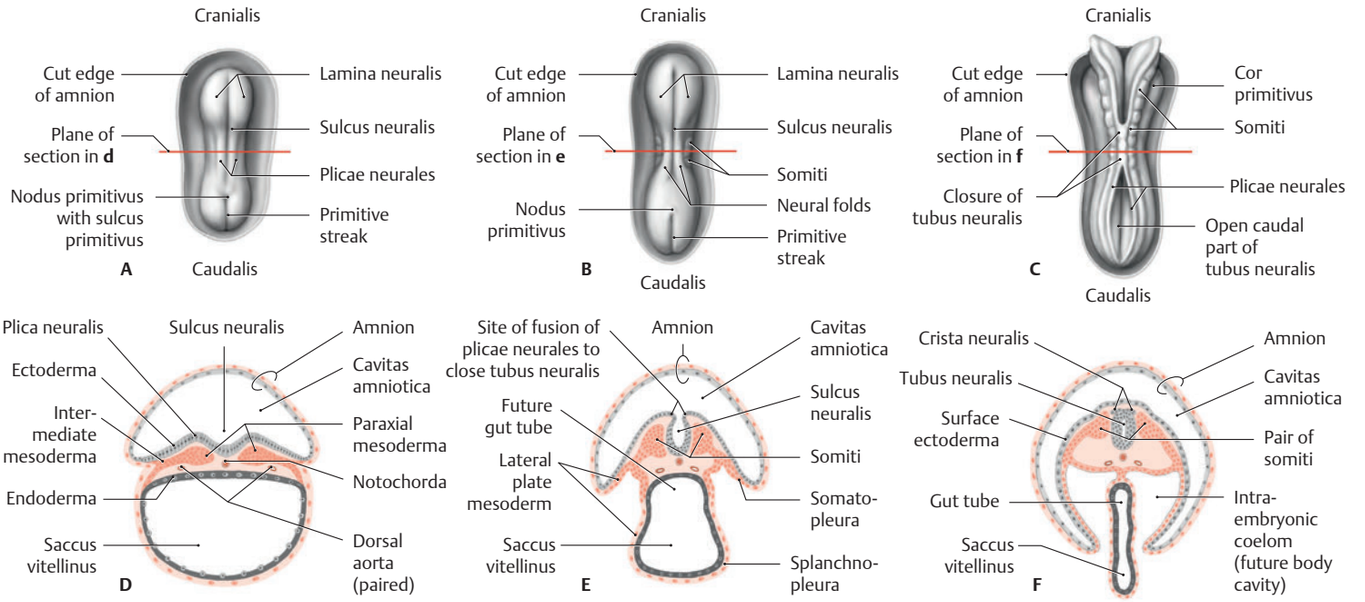


Fig. 1.1 **Embryonic development** (after Sadler)
Age in postovulatory days.
A-C Posterior (dorsal) view after removal of the amnion.
D-E Schematic cross-sections of the corresponding stages at the horizontal planes of section marked in **A** to **C**. Gastrulation occurs in week 3 of human embryonic development. It produces three germ layers in the discus embryonicus: ectoderma (light grey), mesoderma (red), and endoderma (dark grey).
A, D Day 19, the three layers are visible in the discus embryonicus. The amnion forms the cavitas amniotica dorsally and the endoderma encloses the saccus vitellinus. The tubus neuralis is developing in the area of the lamina neuralis.
B, E Day 20, the first somiti have formed, and the sulcus neuralis is beginning to close to form the tubus neuralis, with initial folding of the embryo.
C, F Day 22, eight pairs of somiti flank the partially closed tubus neuralis, which has sunk below the ectoderma. The saccus vitellinus elongates ventrally to form the gut tube and saccus vitellinus. At the sites where the plicae neurales fuse to close the tubus neuralis, cells form a bilateral crista neuralis that detaches from the surface and migrates into the mesoderma.

Table 1.1 **Differentiation of germ layers**

Germ layer	Embryonic structure		Adult derivative
Ectoderma	Tubus neuralis		Encephalon, retina, medulla spinalis
	Crista neuralis	Crista neuralis of the head	Sensory and parasympathetic ganglia, enteric nervous system, parafollicular cells, smooth muscle, pigment cells, globus caroticus, cartilage, connective tissue, dentinum and cementum of the dentes, dermis and tela subcutanea of the caput
		Crista neuralis of the trunk	Sensory and autonomic ganglia, peripheral glia, medulla glandulae suprarenalis, pigment cells, intramural plexuses
	Surface ectoderma	Placodae	Adenohypophysis, cranial sensory ganglia, olfactory epithelium, auris interna, lens
			Epithelium of the cavitas oris, glandulae salivariae, cavitates nasi, sinus paranasales, lacrimal passages, meatus acusticus externus, epidermis, hair, nails, cutaneous glands
Mesoderma	Paraxial	Somiti	Corium of skin (from dermatome), musculature (from myotome), columna vertebralis (from sclerotome)
	Axial	Notochorda	Musculi externi bulbi oculi
	Intermediate		Renes, gonads, renal and genital excretory ducts
	Lateral plates	Visceral	Cor, blood vessels, smooth muscle, bowel wall, blood, cortex glandulae suprarenalis, visceral serosa
		Parietal	Sternum, limbs without muscles, dermis and tela subcutanea of the anterolateral body wall, smooth muscle, connective tissue, parietal serosa
Endoderma	Intestinal tube		Epithelium of the bowel, respiratory tract, digestive glands, glandulae pharyngeae, tuba auditiva, cavitas tympani, vesica urinaria, glandulae parathyroideae, glandula thyroidea

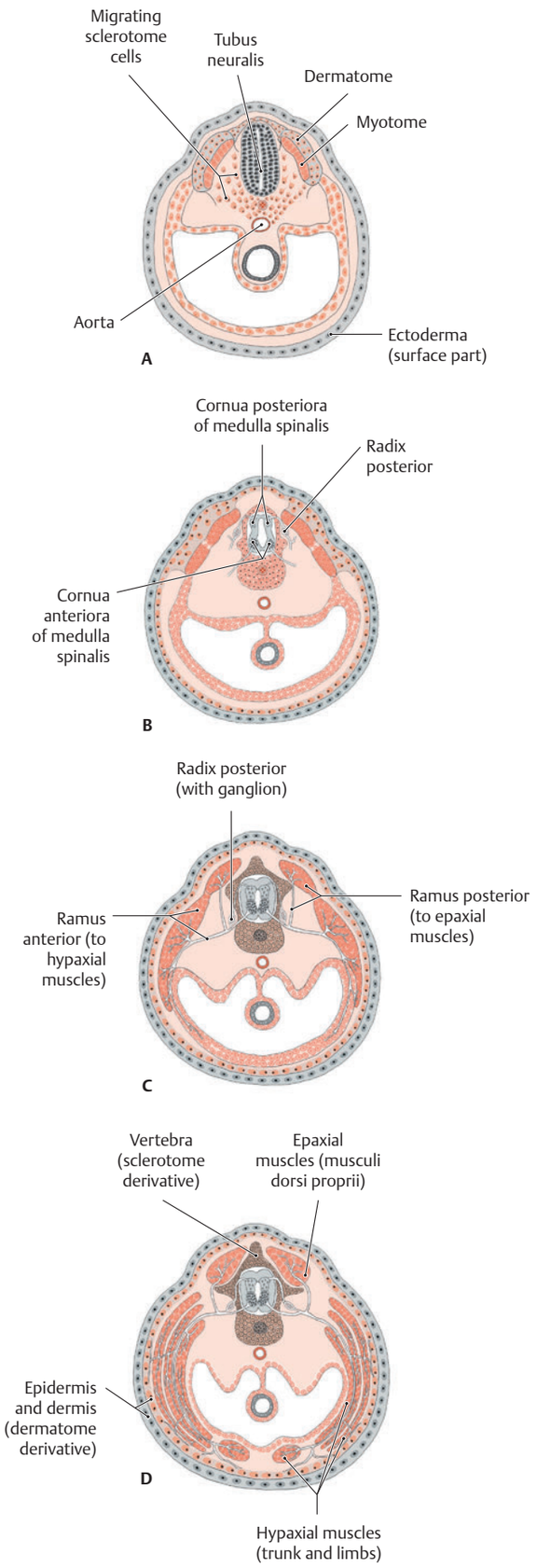


Fig. 1.2 **Somatic muscle development**
Age in postovulatory days. Each somitus divides into a dermatome (cutaneous), myotome (muscular), and sclerotome (vertebral) at around day 22 (see Fig 1.1).
A Day 28, sclerotomes migrate to form the columna vertebralis around the notochorda (primitive medulla spinalis).
B Day 30, all 34 or 35 somitus pairs have formed. The tubus neuralis differentiates into a primitive medulla spinalis. Motor and sensory neurons differentiate in the cornua anterius and posterius of the medulla spinalis, respectively.
C By day 40, the radices posterior and anterior form the mixed nervus spinalis. The ramus posterior supplies the epiaxial muscles (future musculi dorsi proprii); the ramus anterior supplies the hypaxial muscles (anterior muscles, including all muscles except the musculi dorsi proprii).
D Week 8, the epiaxial and hypaxial muscles have differentiated into the skeletal muscles of the trunk. Cells from the sclerotomes also migrate into the limbs. During this migration, the nervi spinales form the plexus (cervicalis, brachialis, and lumbosacralis), which innervate the muscles of the neck, upper limb, and lower limb, respectively.

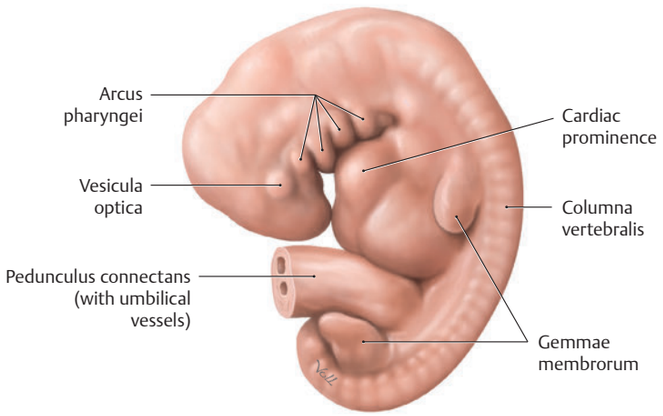


Fig. 1.3 **5-week-old embryo**
The human embryo at 5 weeks has a crown-rump length of approximately 5 to 7 mm. The funiculus umbilicus, which attaches the embryo to the mother, is seen. The future hemispheria cerebri form along with the oculus, auris, arcus pharyngei (which form a large portion of the structures of the caput and collum), cor (which will start beating at around week 6), tubus neuralis, and gemmae membrorum.

Development of the Encephalon & Medulla Spinalis

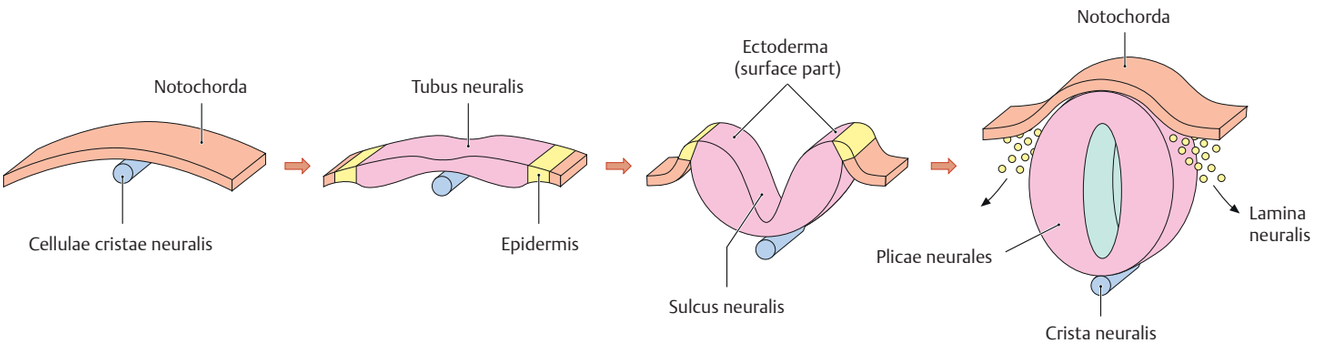


Fig. 1.4 **Development of the tubus neuralis and crista neuralis** (after Wolpert)

The tissues of the nervous system orginate embryonically from the posterior surface ectoderma. The notochorda in the midline of the body induces the formation of the lamina neuralis, which lies above the notochorda, and of the cristae neurales, which are lateral to the notochorda. With further development, the lamina neuralis deepens at the center to form the sulcus neuralis, which is flanked on each side by the plicae neurales. Later the sulcus deepens and closes to form the tubus neuralis, which sinks below the ectoderma. The tubus neuralis is the structure from which the systema nervosum centrale (CNS) – the brain and medulla spinalis–develops (further development of the medulla spinalis is shown in **Fig. 1.5**, further encephalon development in **Fig. 1.7**). Failure of the sulcus neuralis to close completely will leave an anomalous cleft in the columna vertebralis, known as spina bifida. The administration of folic acid to potential mothers around the time of conception can reduce the incidence of spina bifida by 70%. Cells that migrate from the crista neuralis develop into various structures, including cells of the systema nervosum peripheric um (PNS), such as Schwann cells, and the pseudounipolar cells of the ganglion sensorium nervi spinalis (see **Fig. 1.6**).

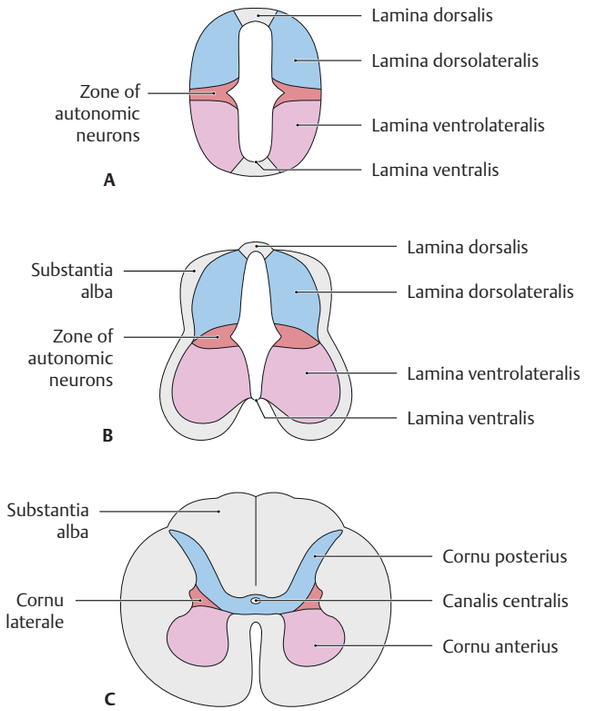


Fig. 1.5 **Differentiation of the tubus neuralis in the medulla spinalis during development**

Cross-section, superior view.

A Early tubus neuralis. **B** Intermediate stage. **C** Adult medulla spinalis. The neurons that form the lamina ventrolateralis are efferent (motor neurons), while the neurons that form the lamina dorsolateralis are afferent (sensory neurons). In the future thoracic, lumbar, and sacral medulla spinalis, there is another zone between them that gives rise to sympathetic (autonomic) efferent neurons. The lamina dorsalis and the lamina ventralis do not form neurons.

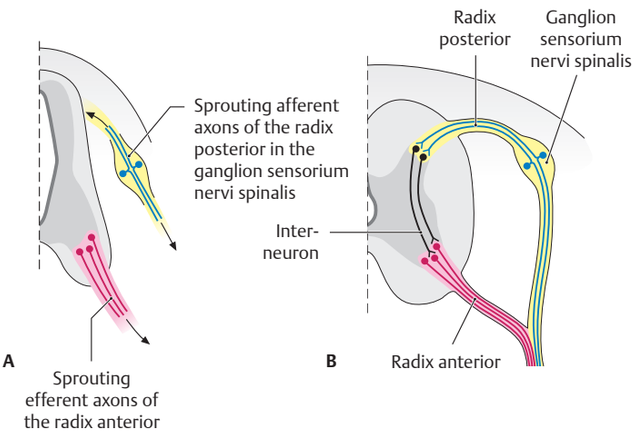


Fig. 1.6 **Development of a peripheral nerve**

Afferent (sensory) axons (blue) and efferent (motor) axons (red) sprout from the neuronal cell bodies during early embryonic development.

A Primary afferent neurons develop in the ganglion sensorium nervi spinalis, and alpha motor neurons develop from the lamina ventrolateralis of the medulla spinalis.

B The interneurons (black), which functionally interconnect the afferent and efferent neurons, develop at a later stage.

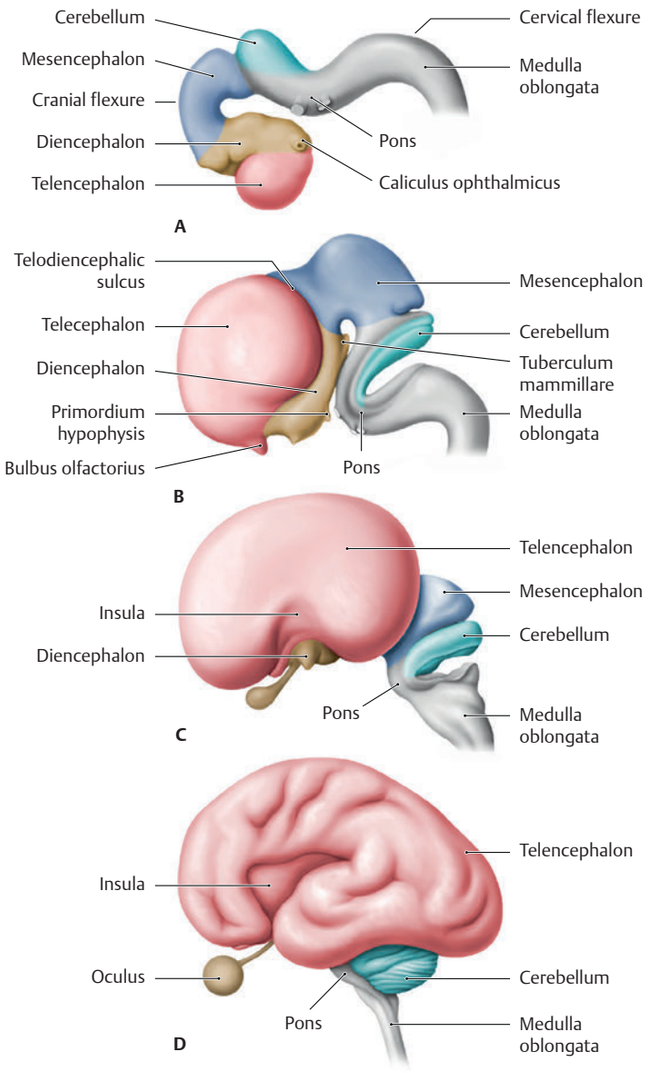


Fig. 1.7 **Development of the encephalon**

A Embryo with the greatest length (GL) of 10 mm at the beginning of the 2nd month of development. Even at this stage, we can see the differentiation of the tubus neuralis into segments that will generate various brain regions.

- Red: telencephalon (cerebrum)
- Yellow: diencephalon
- Dark blue: mesencephalon (midbrain)
- Light blue: cerebellum
- Gray: pons and medulla oblongata

Note: The telencephalon outgrows all of the other brain structures as development proceeds.

B Embryo with a GL of 27 mm near the end of the 2nd month of development (end of the embryonic period). The telencephalon and the diencephalon have enlarged. The bulbus olfactorius is developing from the telencephalon, and the primordium of the hypophysis is developing from the diencephalon.

C Fetus with a GL of 53 mm in approximately the 3rd month of development. By this stage the telencephalon has begun to cover the other brain areas. The insula is still on the brain surface but will subsequently be covered by the hemispheria (compare with **D**).

D Fetus with GL of 27 cm (270 mm) in approximately the 7th month of development. The cerebrum (telencephalon) has begun to develop well-defined gyri and sulci.

Table 1.2 **Development of the encephalon**

Primary vesicle		Region		Structure
Tubus neuralis	Prosencephalon (forebrain)	Telencephalon		Cortex cerebri, substantia alba, nuclei basales
		Diencephalon		Epithalamus (pineal gland), dorsal thalamus, subthalamus, hypothalamus
	Mesencephalon (midbrain)*			Tectum, tegmentum mesencephali, pedunculus cerebri
	Rhombencephalon (hindbrain)	Metencephalon	Cerebellum	Cortex cerebelli, nuclei, pedunculi cerebellares
			Pons*	Nuclei, fiber tracts
		Myelencephalon	Medulla oblongata*	

*The mesencephalon, pons, and medulla oblongata are collectively known as the truncus encephali.

Development & Derivatives of the Arcus Pharyngei

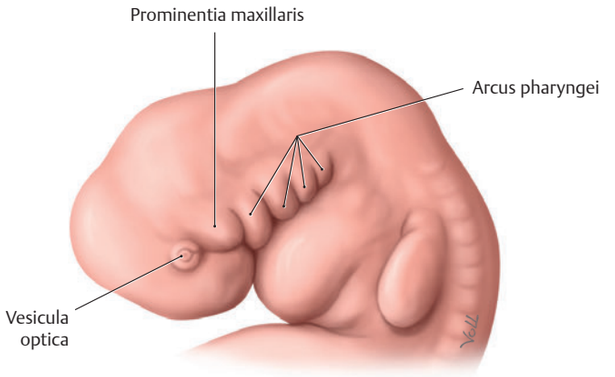


Fig. 1.8 **Head and neck region of a 5-week-old embryo, showing the arcus and sulci pharyngei**
Left lateral view. The arcus pharyngei are instrumental in the development of the face, neck, larynx, and pharynx. Development of the arcus pharyngei begins in the 4th week of embryonic life as cells migrate from the crista neuralis to the future head and neck region. Within 1 week, a series of four cristae obliquae (first through fourth arcus pharyngei) form that are located at the level of the cranial segment of the foregut and are separated externally by four deep sulci (sulci pharyngei). The arcus and sulci pharyngei are prominent features of the embryo at this stage.

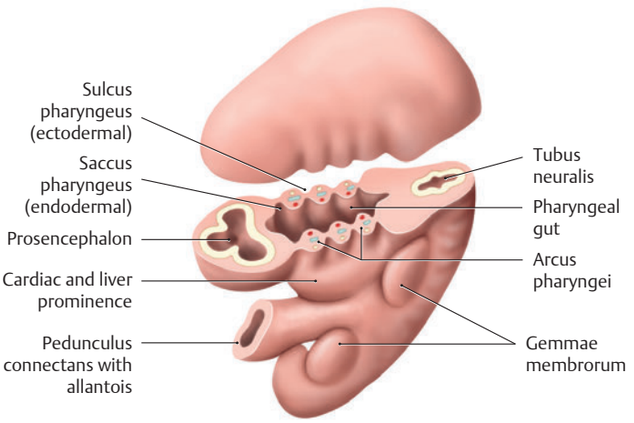
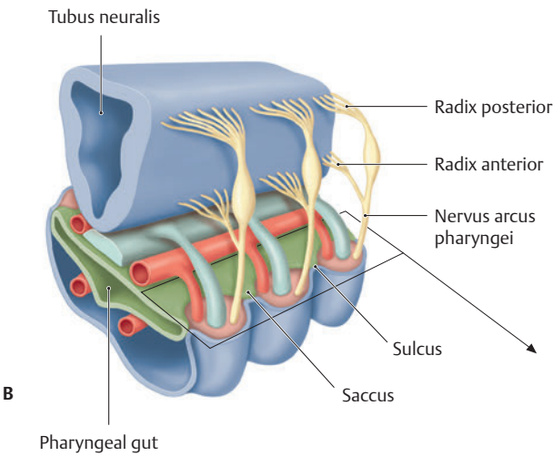


Fig. 1.9 **Cross-section through an embryo at the level of the pharyngeal gut** (after Drews)
Left superior oblique view. Due to the craniocaudal curvature of the embryo, the cross-section passes through the arcus pharyngei and pharyngeal gut as well as the prosencephalon and medulla spinalis. The pharyngeal gut is bounded on both sides by the arcus pharyngei, which contain the mesodermal core. They are covered externally by ectoderm and internally by endoderm. Ectodermal sulci pharyngei and endodermal sacci pharyngei lie directly opposite one another. Because the embryo is curved craniocaudally, the pharyngeal gut and arcus pharyngei overlie the prominence of the rudimentary heart and liver.



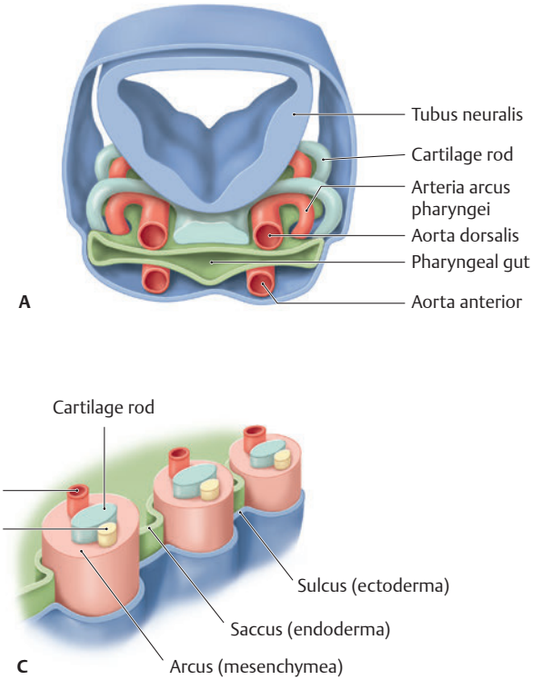


Fig. 1.10 **Structure of the arcus pharyngei** (after Sadler)
A Cross-section through an arcus pharyngeus and the tubus neuralis, showing the cartilago and arteria arcus pharyngei. **B** Oblique cross-section through an arcus pharyngeus and the tubus neuralis, showing the nervi arcus pharyngei. **C** Blow up of section in **B**, showing the relationship of cartilago, arteria, and nervus in the arcus pharyngei.
The arcus pharyngei are covered externally by ectoderma (blue) and internally by endoderma (green). Each arcus pharyngeus contains an arteria arcus, an nervus arcus, and a cartilaginous skeletal element, all of which are surrounded by mesenchyma and muscular tissue. The external grooves are called the sulci pharyngei, and the internal grooves are called the sacci pharyngei.

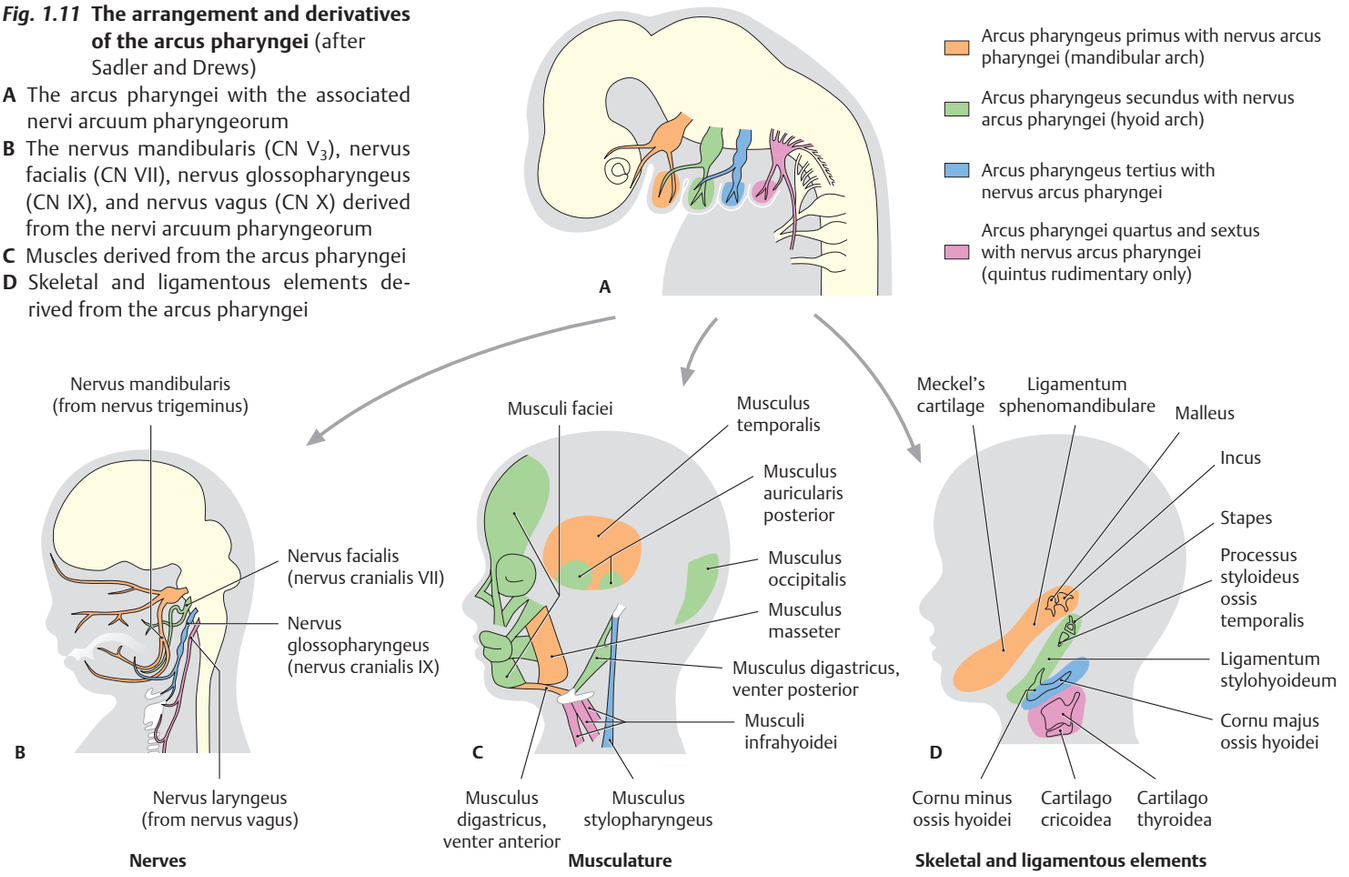


Fig. 1.11 **The arrangement and derivatives of the arcus pharyngei** (after Sadler and Drews)

A The arcus pharyngei with the associated nervi arcuum pharyngeorum

B The nervus mandibularis (CN V_3), nervus facialis (CN VII), nervus glossopharyngeus (CN IX), and nervus vagus (CN X) derived from the nervi arcuum pharyngeorum

C Muscles derived from the arcus pharyngei

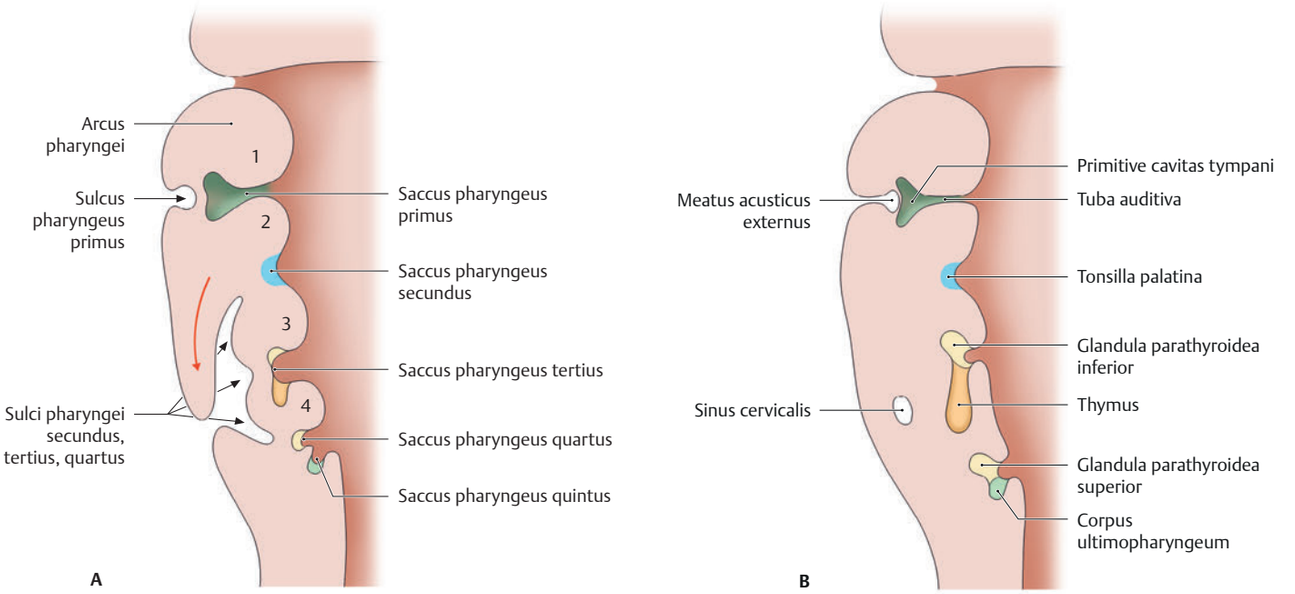
D Skeletal and ligamentous elements derived from the arcus pharyngei

Table 1.3 **Derivatives of the arcus pharyngei**

Arcus pharyngeus	Muscles*		Skeletal and ligamentous elements	Nerve accompanying arch
1	Muscles of mastication • Musculus temporalis • Musculus masseter • Musculus pterygoideus lateralis • Musculus pterygoideus medialis Musculus mylohyoideus Venter anterior musculi digastrici Musculus tensor tympani Musculus tensor veli palatini		Maxilla Mandibula Os zygomaticum Os palatinum Vomer Pars squamosa ossis temporalis Malleus and incus Meckel's cartilage Ligamentum sphenomandibulare Ligamentum mallei anterius	Nervus mandibularis (CN V_3)
2	Musculi faciei Musculus styloideus Venter posterior musculi digastrici Musculus stapedius		Stapes Processus styloideus ossis temporalis Cornu minus ossis hyoidei Upper part, os hyoideum	Nervus facialis (CN VII)
3	Musculus stylopharyngeus		Cornu majus ossis hyoidei Lower part, os hyoideum	Nervus glossopharyngeus (CN IX)
4 and 6	Pharyngeal muscles • Musculus levator veli palatini • Musculus uvulae • Musculus palatoglossus • Musculus salpingopharyngeus • Musculus palatopharyngeus • Musculi constrictores pharyngis	Laryngeal muscles • Musculus thyroarytenoideus • Musculus vocalis • Musculus cricoarytenoideus lateralis • Musculus cricothyroideus • Musculi arytenoidei obliqui • Musculi arytenoidei transversi • Musculi arytenoidei posteriores • Pars aryepiglottica musculi thyroarytenoidei • Pars thyroepiglottica musculi arytenoidei obliqui	Laryngeal skeleton • Cartilago thyroidea • Cartilago cricoidea • Cartilago arytenoidea • Tuberculum corniculatum • Tuberculum cuneiforme	Nervus vagus (CN X)

Abbreviation: CN, nervus cranialis.
*All branchial skeletal muscles

Development & Derivatives of the Sacci Pharyngei, Membranae Pharyngeae, & Sulci Pharyngei



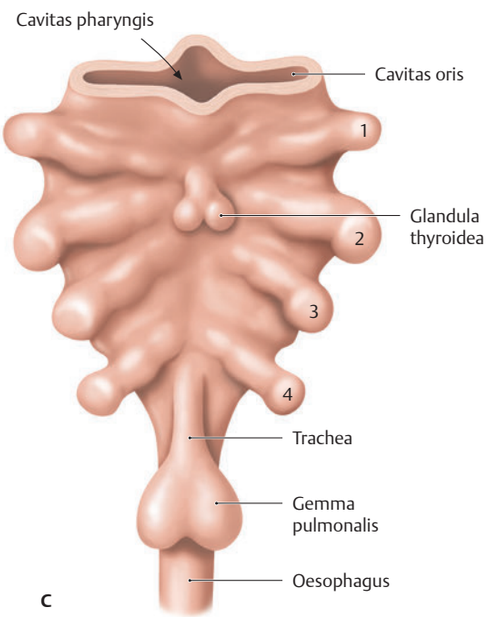


Fig. 1.12 **Development of the sacci pharyngei, membranae pharyngeae, and sulci pharyngei**
A Schematic view of developing sacci and sulci pharyngei.
B Schematic view of adult structures formed by sacci pharyngei.
C Three-dimensional representation of the sacci pharyngei and their relationship to the cavitas oris, cavitas pharyngis, and structures of the neck.
The sacci pharyngei are paired, diverticula-like outpouchings of the endodermal pharyngeal gut. A total of four distinct sacci pharyngei develop on each side; the fifth is often absent or rudimentary. The sacci pharyngei develop into the cavitas tympani and the glandulae endocrinae in the neck.
The sulcus pharyngeus primus develops into the emeatus acusticus externus. The arcus pharyngeus secundus grows over the arcus pharyngei tertius and quartus and as it does so it buries the sulci pharyngei secundus, tertius, and quartus pharyngeal clefts. Remnants of these clefts form the sinus cervicalis, which is normally obliterated.
The membranae pharyngeae separate the sacci pharyngei from the sulci pharyngei in the developing embryo. They collectively develop into the membrana tympanica.

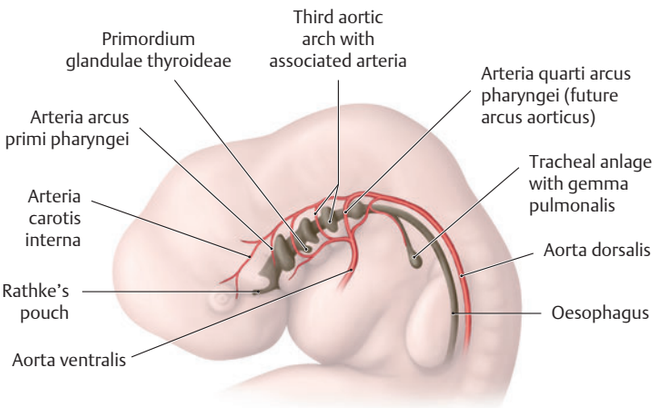


Fig. 1.13 **Pharyngeal pouches and the aortic arch** (after Sadler)
The arteriae arcuum pharyngeorum arise from the paired embryonic aortae ventrales and run between the sacci pharyngei. They open posteriorly into the aortae dorsales, which is also paired. The definitive arcus aortae develops arteria quarti arcus pharyngei sinistri.
Note: The pouch protruding from the roof of the cavitas oris is called Rathke's pouch (precursor of the adenohypophysis). Note also the gemma pulmonalis extending anteriorly from the pharyngeal gut, and the primordium glandulae thyroideae.

Table 1.4 **Derivatives of the sacci pharyngei**

Pouch	Germ layer	Embryonic structure	Adult structure
1	Endoderma	Tubotympanic recess	Epithelium of the tuba auditiva Cavitas tympani
2		Primitive tonsillae palatinae	Fossa tonsillaris Epithelium of the tonsilla palatina
3		Divides into a posterior and an anterior part at its distal end	Glandula parathyroidea inferior (from posterior part) Thymus (from anterior part)
4		Divides into a posterior and an anterior part at its distal end	Glandula parathyroidea superior (from posterior part) corpus ultimopharyngeum (from anterior part). This is later incorporated in glandula thyroidea and gives rise to the parafollicular or C cells, which secrete calcitonin.

Table 1.5 **Derviative of the membranae pharyngeae**

Membranes	Germ layers	Adult structure
1 to 4	Composed externally of ectoderma and internally of endoderma. The intervening core consists of mesoderma and crista neuralis cells.	Membrana tympanica

Table 1.6 **Derivatives of the pharyngeal clefts**

Cleft	Germ layer	Adult structure
1	Ectoderma	Meatus acusticus externa
2 to 4		Sinus cervicalis, which is rapidly obliterated by the arcus pharyngeus secundus, which grows over sulci II to IV

Treacher Collins syndrome is a rare autosomal dominant craniofacial defect involving the structures derived from the arcus pharyngeus primus. It is characterized by malar hypoplasia (underdevelopment or incomplete development of the cheek), mandibular hypoplasia, downslanting eyes, eyelid coloboma (notching of the lower eyelids), and malformed aures externae. It may also be associated with cleft palate, hearing loss (due to defects in the ossicles), vision loss, and difficulty breathing (dyspnea). Treatment will depend on the severity of the defects but will involve a multidisciplinary team of clinicians.

Pierre-Robin syndrome is characterized by an abnormally small mandibula (micrognathia). As a result, the tongue musculature is unsupported by the mandibula, allowing it to displace posteriorly, partially obstructing the airway, resulting in dyspnea (shortness of breath). This posterior displacement of the tongue (glossoptosis) is also responsible for cleft palate because it prevents the processus palatini laterales from fusing (see **Figs. 1.21** and **1.22**). Initial treatment involves surgery to repair the cleft palate to improve feeding and speech development.

Development of the Lingua & Glandula Thyroidea

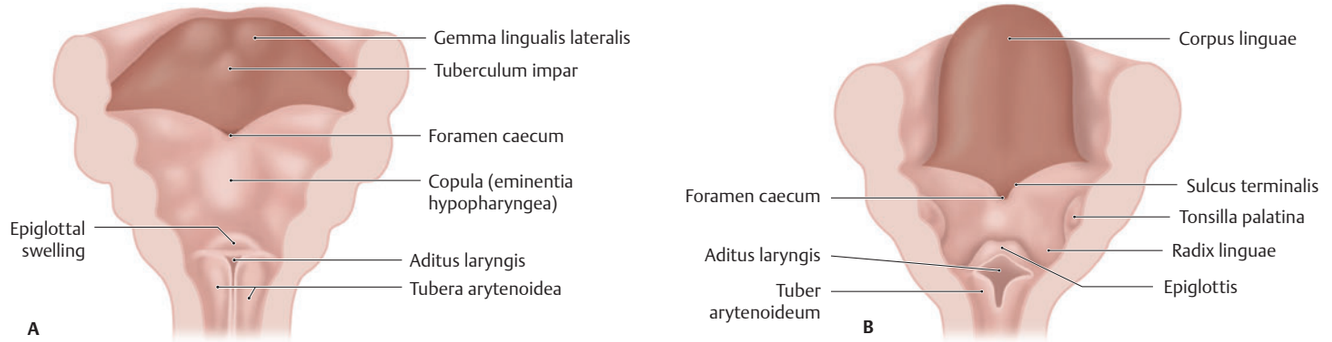


Fig. 1.14 **Development of the lingua**
A Early tongue development, around week 4. **B** Late tongue development, around week 8.

The lingua develops within the pharynx. While the musculature of the lingua is derived from somiti, the lingua develops from the four gemmae linguales. Three gemmae are associated with the arcus pharyngeus primus and one, with the arcus tertius, quartus, and sextus. The two gemmae linguales laterales and one gemma lingualis mediana (the tuberculum impar) from the arcus pharyngeus primus contribute to the development of the anterior two thirds of the lingua. The single midline swelling (the eminentia hypopharyngea [copula]) from the arcus tertius, quartus, and sextus contributes to the development of the posterior one third of the lingua. A U-shaped sulcus develops around the lingua allowing it to move freely, except in one area, which is the frenulum linguae, which anchors the lingua to the floor of the cavitas oris.

The lingual mucosa derived from the arcus primus swelling that covers the anterior two thirds of the tongue is innervated by the nervus mandibularis division of the nervus trigeminus; the lingual mucosa derived from the arcus tertius, quartus, and quintus swellings receives sensory innervation from both CN IX (nervus hypoglossus) and CN X (nervus vagus).

The V-shaped (sulcus terminalis) separates the anterior two thirds of the lingua from the posterior one third. Located at the vertex of the sulcus terminalis, between the tuberculum impar and the eminentia hypopharyngea, the foramen caecum marks the site of exit for the glandula thyroidea from the floor of the inside of the pharynx to an extrapharyngeal location.

Ankyloglossia (tongue-tie) is a congenital anomaly in which the frenulum linguae is unusually short or thick, thereby tethering the ventral surface of the tip of the lingua to the floor of the mouth. Clinical features include restricted elevation, protrusion, and side-to-side movement of the lingua, and demonstration of a heart-shaped lingua on protrusion. It may be noticed as difficulty feeding in infants. Treatment, when required, involves a frenectomy, where the frenulum is incised, releasing the lingua.

Table 1.7 **Derivation of the lingua**

Arcus pharyngeus	Embryonic structure(s)	Adult structure	Innervation
1	Two gemmae linguales laterales Tuberculum impar	Anterior two thirds of the lingua	GSA: nervus lingualis branch of the nervus mandibularis division of the nervus trigeminus (CN V_3)
2	Is obliterated by the arcus pharyngeus tertius and therefore does not contribute to the adult lingua Eminentia hypopharyngea (minor involvement)	-	-
3	Eminentia hypopharyngea	Posterior one third of the lingua	GSA: nervus glossopharyngeus (CN IX) SVA: nervus glossopharyngeus (CN IX)
4	Eminentia hypopharyngea Epiglottic swelling Tuber arytenoideum Sulcus laryngotrachealis	Radix linguae	GSA:ramus internus nervi laryngei superioris branch of the nervus vagus (CN X) SVA: ramus internus nervi laryngei superioris branch of the nervus vagus (CN X)

Abbreviations: GSA, general somatic afferent; SVA, special visceral afferent

Table 1.8 **Derivation of the skeletal muscles of the lingua**

Muscle origin	Muscles	Nervi craniales
Somiti (from myotomes)	Intrinsic muscles of the lingua Extrinsic muscles of the lingua (musculi genioglossus, styloglossus, and hyoglossus; ***not*** musculus palatoglossus)	Nervus hypoglossus (CN XII)

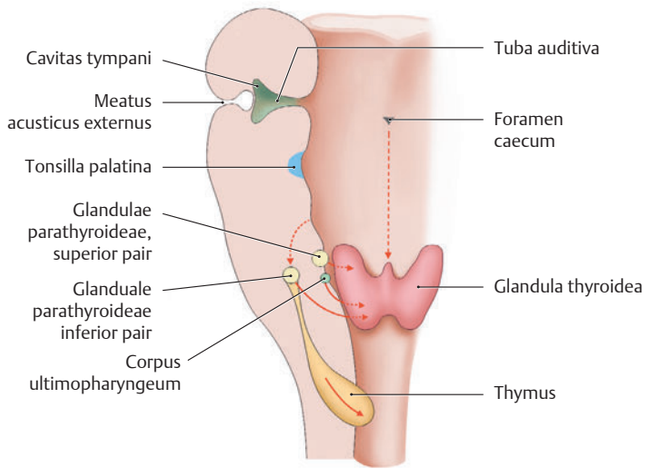


Fig. 1.15 **Migration of the arcus pharyngeus tissues** (after Sadler)
Anterior view. During embryonic development, the epithelium from which the glandula thyroidea forms migrates from its site of origin on the basal midline of the lingua to the level of the first tracheal cartilage, where the glandula thyroidea is located in postnatal life. As the thyroid tissue buds off from the lingua base, it leaves a vestigial depression on the dorsum linguae, the foramen caecum. The glandulae parathyroideae are derived from the arcus pharyngeus quartus (superior pair) or the arcus pharyngeus tertius (inferior pair), which also gives rise to the thymus. The ultimobranchial body, whose cells migrate into the glandula thyroidea to form the calcitonin-producing C cells, or parafollicular cells, is derived from the 5th vestigial arcus pharyngeus. The latter arch is the last to develop and is usually considered part of the arcus pharyngeus quartus. The meatus acusticus externus is derived from the sulcus pharyngeus primus, the cavitas tympani and tuba auditiva from the saccus pharyngeus primus, and the tonsilla palatina from the saccus pharyngeus secundus.
Ectopic thyroid is a rare condition in which the entire glandula thyroidea or thyroid tissues are not found in their normal position in the neck, i.e., inferolateral to the cartilago thyroidea. Dentists may encounter this as a firm midline mass, which may appear as light pink to bright red, and may be regular or irregular on the dorsum linguae, just posterior to the foramen caecum (the embryonic origin of the glandula thyroidea). This is known as a lingual thyroid and represents approximately 90% of ectopic thyroid cases. Symptoms of lingual thyroid may include cough, pain, difficulty swallowing (dysphagia), difficulty speaking (dysphonia), and difficulty breathing (dyspnea).

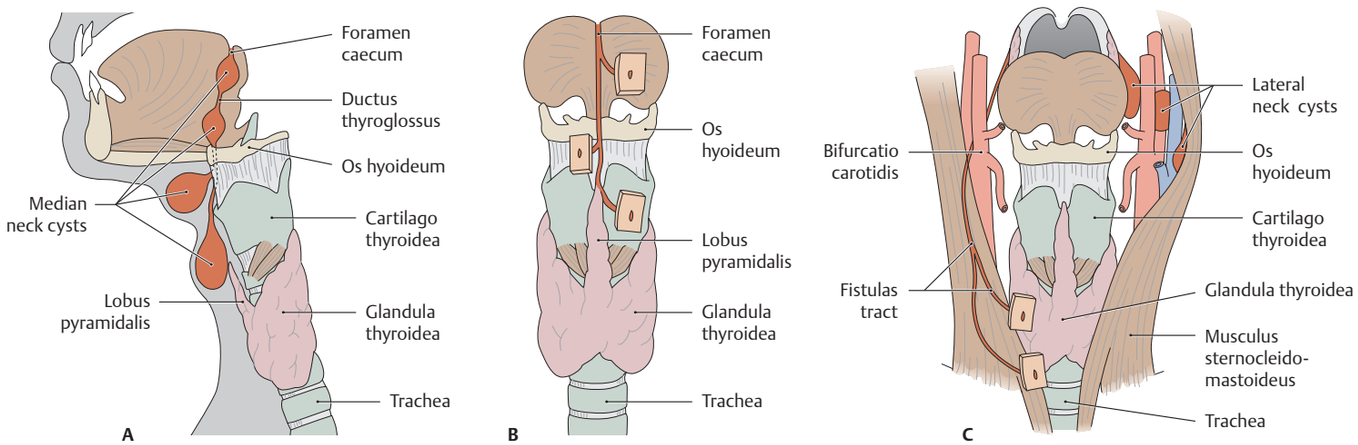


Fig. 1.16 **Location of cysts and fistulas in the neck**
A Median cysts. **B** Median fistulas. **C** Lateral fistulas and cysts.

A, B Median cysts and fistulas in the neck are remnants of the ductus thyroglossus. Failure of this duct to regress completely may lead to the formation of a mucus-filled cavity (cyst), which presents clinically as a palpable, fluctuant, midline swelling in the neck at around the level of the os hyoideum. It is seen to move upward on swallowing or protrusion of the lingua due to the connection of the lingua with the duct. Symptoms may include dyspnea (difficulty breathing), dysphagia (difficulty swallowing), and pain (only if the cyst becomes infected).

C Lateral cysts and fistulas in the neck are anomalous remnants of the ductal portions of the sinus cervicalis, which forms as a result of tissue migrations during embryonic development.
If epithelium-lined remnants persist, neck cysts (right) or fistulas (an abnormal communication between structures; left) may appear in postnatal life. A complete fistula opens into the pharynx and onto the surface of the skin, whereas an incomplete (blind) fistula is open at one end only. The external orifice of a lateral cervical fistula is typically located at the anterior border of the musculus sternocleidomastoideus.

Development of the Face

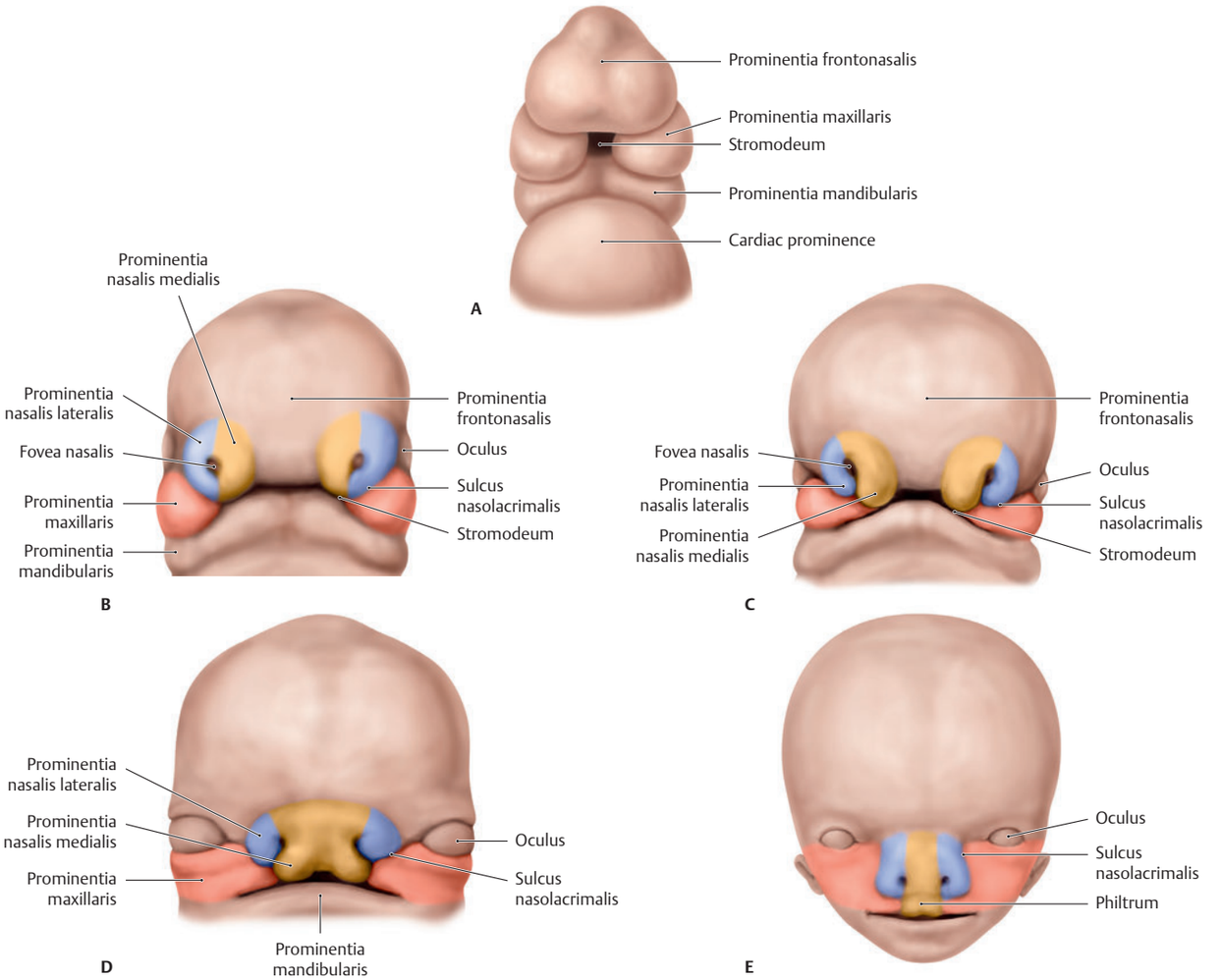


Fig. 1.17 **Development of the face** (after Sadler)
A Anterior view at 24 days. The surface ectoderma of the arcus pharyngeus primus invaginates to form the *stromodeum*, which is a depression between the prosencephalon and the pericardium in the embryo. It is the precursor of the mouth, cavitas oris, and the adenohypophysis. At this stage, the stromodeum is separated from the primitive pharynx by the buccopharyngeal (oropharyngeal) membrane. This membrane later breaks down and the stromodeum becomes continuous with the pharynx.
The stromodeum is surrounded by five neural-crest-cell–derived mesenchymal swellings, known as *prominentiae*, which contribute to the development of the face.
B Anterior view at 5 weeks. Placodae nasales, ectodermal thickenings, form on each side of the prominentia frontonasalis. Invagination of the placodae nasales into the prominentia frontonasalis leads to the formation of the prominentiae nasales lateralis and medial is. The placodae now lie in the floor of a depression known as the *fovea nasalis*. The prominentiae maxillares continue to increase in size and merge laterally with the prominentiae mandibulares to form the cheek. Medially, the prominentiae maxillares compress the prominentiae nasales mediales toward the midline. A furrow (the sulcus nasolacrimalis) separates the prominentiae nasales from the prominentia maxillaris. Ectoderma from the floor of the sulcus nasolacrimalis will give rise to the ductus nasolacrimalis that connects the orbita with the cavitas nasi; the two prominences will join to close the groove and create the canalis nasolacrimalis.
C Anterior view at 6 weeks. The prominentiae nasales mediales enlarge, grow medially, and merge with each other to form the intermaxillary segment.
D Anterior view at 7 weeks. The prominentiae nasales mediales have fused with each other along the midline and with the prominentiae maxillares and their lateral margins.
E Anterior view at 10 weeks. Cell migration is complete.

Table 1.9 **Prominences contributing to facial structures**

Prominence	Facial structure
Prominentia fronto-nasalis	Forehead, nose, prominentiae nasales medialis and lateralis
Prominentiae maxillares	Cheeks, lateral parts of the labium superius
Prominentiae nasales mediales	Philtrum of the labium superius, dorsum and apex nasi
Prominentiae nasales laterales	Alae nasi
Prominentiae mandibulares	Labium inferius

*The prominentia frontonasalis is a single unpaired structure; all other prominences listed as paired.

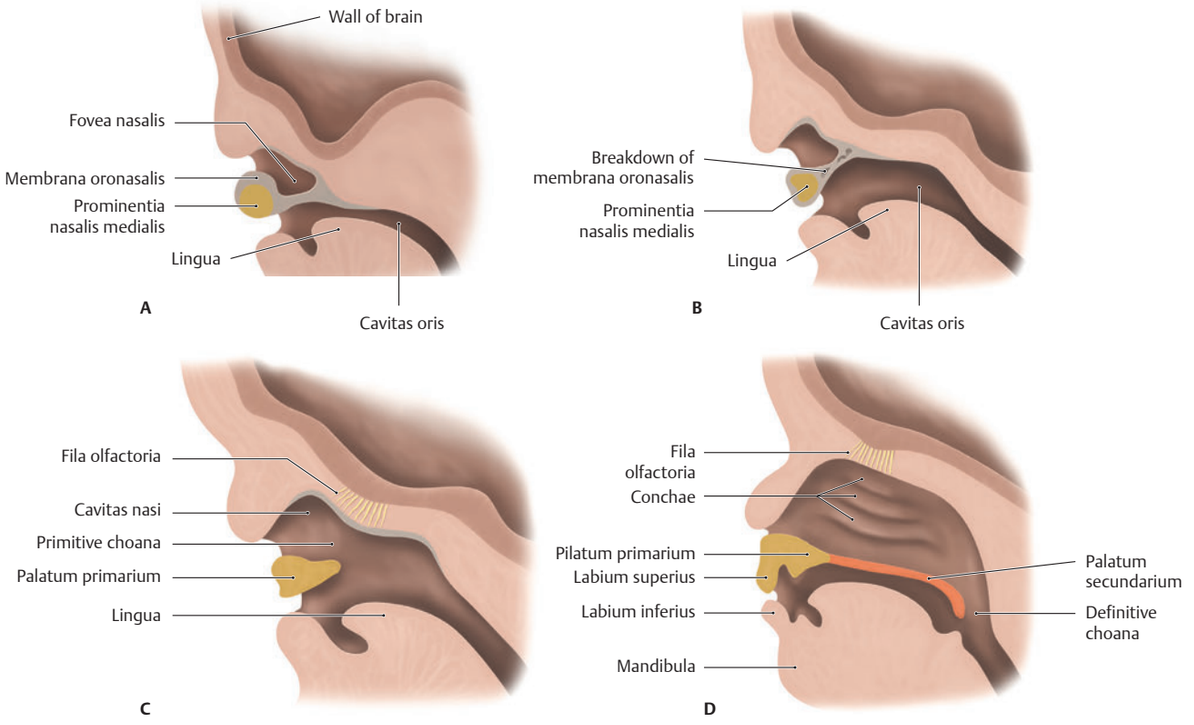


Fig. 1.18 **Development of the cavitas nasi**
Sagittal section of embryo. At week 6, the primitive cavitas nasi is separated from the cavitas oris by the membrana oronasalis **(A)**, which then breaks down **(B)**, leaving the cavitates nasi and oris in open connection by week 7 **(C)**. In week 9, the cavitas nasi and cavitas oris are in their definitive arrangement **(D)**, separated by the palata primarium and secundarium with choanae at their junction in the pharynx. The lateral walls of the cavitas nasi develop the conchae superior, media, and inferior. The ectodermal epithelium in the roof of the cavitas nasi becomes the specialized olfactory epithelium. The olfactory cells within the olfactory epithelium give rise to the fila olfactoria (CN I) that grow into the bulbus olfactorius. The septum nasi (not shown) develops as a downgrowth of the merged prominentiae nasales mediales. It fuses with the processus palatinus by weeks 9 to 12.

Fig. 1.19 **Development of the oculi and aures**
At about 22 days, the oculi and aures begin to develop. The oculi develop laterally in the embryo but during growth move medially to occupy their familiar position on the face. The auricula of the auris is formed from six swellings, known as *colliculi auriculares*, from the sacci pharyngei primus and secundus. The germ layers that contribute to the oculi and aures are listed in **Table 1.10**.

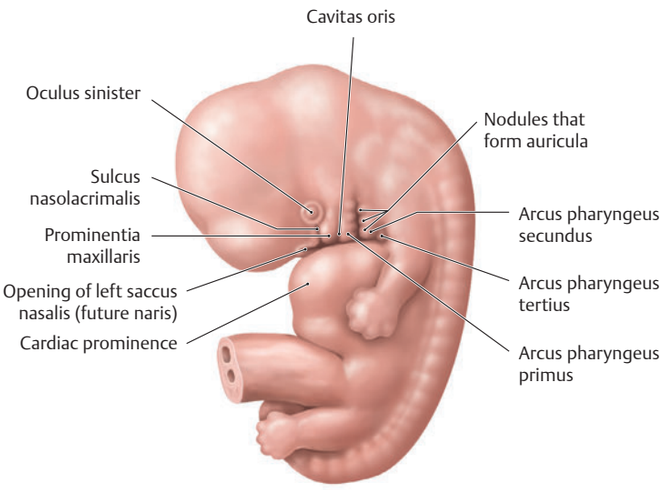


Table 1.10 **Derivation of the structures of the oculus and auris**

Germ layer	Structure
Oculus	
Surface ectoderma	Corneal and conjunctival epithelium, lens, glandulae lacrimales, glandulae tarsales
Crista neuralis cell ectoderma (neuroectoderm)	Retina, nervus opticus (CN I), iris
Mesenchyma	Corneal stroma, sclera, choroidea, iris, parts of corpus vitreum, musculus ciliaris, muscles lining the camera anterior
Auris	
Ectoderma	Meatus acusticus externus
Endoderma	Auricula
Mesenchyma	Organum vestibulocochleare

Development of the Palatum

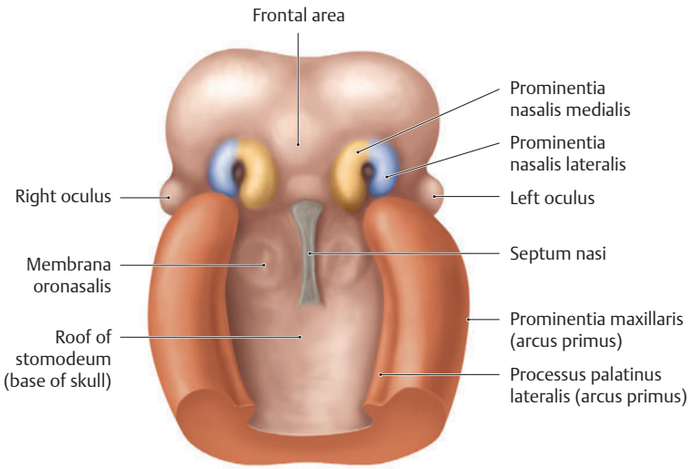


Fig. 1.20 **Palatum formation, 7- to 8-week-old embryo**
Inferior view. Before the palatum has formed, the cavitas oris is open to the cavitas nasi. The septum nasi can be seen as well as the membrana oronasalis, which will ultimately form the choana. Development of the palatum begins during week 5, but fusion of its parts is not complete until week 12. The most critical period for palatum development is between the end of week 6 and the beginning of week 9. The palatum forms from two major parts, the palata primarium and secundarium. The palatum primarium is derived from the wedge-shaped intermaxillary segment, which is formed by the merging of the two prominentiae nasales mediales. The palatum secundarium is derived from two shelf-like outgrowths of the prominentia maxillaris, which, at this stage, are directed downward beside the lingua (removed).

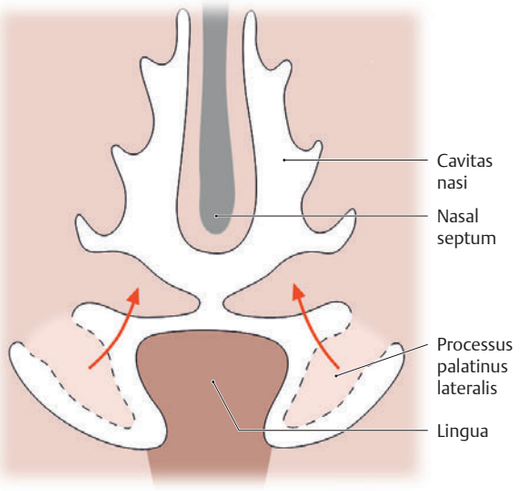


Fig. 1.21 **Elevation of the processus palatini laterales**
The processus palatini laterales, which form the palatum secundarium, are seen at around 6 weeks and are directed obliquely downward on each side of the lingua. At around 7 weeks, the processus palatini laterales ascend to a horizontal position above the lingua and fuse.

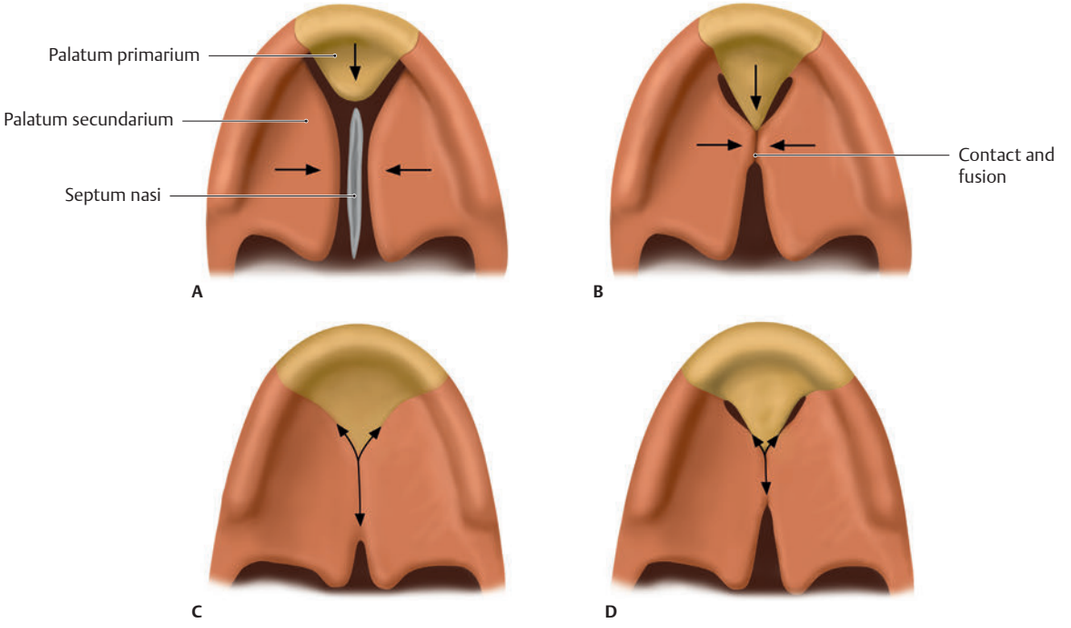


Fig. 1.22 **Fusion and merging of the processus palatini laterales**
Fusion of the palatum begins at around 9 weeks and is completed posteriorly by week 12. **(A)** The palatum primarium and both halves of the palatum secundarium migrate toward each other as indicated by the arrows. **(B)** They contact and fuse at a point (marked by the foramen incisivum) and merge anteriorly and posteriorly, as shown in **(C)** and **(D)**. The palata primarium and secundarium ossify, forming the palatum durume. The posterior portions of the processus palatini laterales do not become ossified but extend beyond the septum nasi to form the palatum molle and uvula.

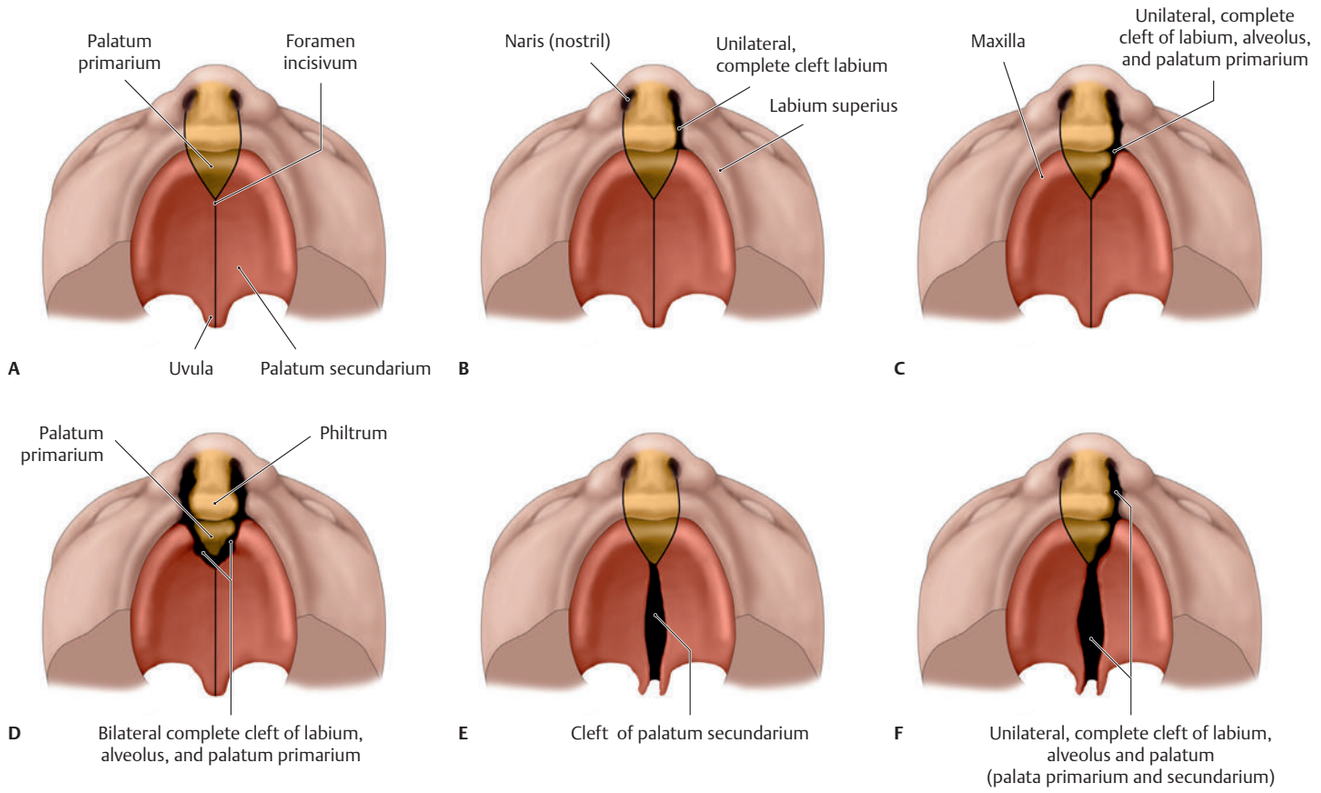


Fig. 1.23 **Formation of facial clefts** (after Sadler)
Inferior view.
Clefts (fissures or openings) can involve the labium and/or the palatum. Clefts are classified as isolated (cleft lip or cleft palate), unilateral or bilateral, and as complete (when they cross the nasal philtrum) or incomplete (if they do not cross the nasal philtrum).
A Normal labium and palatum, in which the prominentiae maxillares and prominentiae nasales mediales have merged to form the labium superius and palatum primarium. The palatum primarium has also fused with the processus palatini of the prominentiae maxillares (palata primarium) to form the complete, unified, palatum durum. The posterior portion of the palatum secundarium is unossified and forms the palatum molle and uvula.
B Unilateral, complete cleft labium results from failure of fusion of the maxillary prominence with the prominentia nasalis medialis on the affected side.
C Unilateral, complete cleft lip, alveolus, and palatum primarium (part of palatum anterior to the foramen incisivum) results from failure of fusion of the prominentia maxillaris with the prominentia nasalis medialis on the affected side.
D Bilateral, complete cleft labium, alveolus, and palatum primarium result from failure of the prominentiae maxillares to fuse with the prominentiae nasales mediales on both sides.
E Cleft of palatum secundarium (part of palatum posterior to the foramen incisivum) results from incomplete fusion of the two processus palatini laterales.
F Unilateral, complete cleft labium and complete cleft palatum (involving both palata primarium and secundarium) result from failure of fusion of the prominentia maxillaris with the prominentia nasalis medialis and failure of fusion of the two processus palatini laterales on the affected side.
Cleft labium and palatum can cause difficulty in eating and speaking, and result in failure to thrive in infants. Treatment by a multidisciplinary team of healthcare professionals principally involves corrective surgery, which is usually performed between 6 and 12 months of age, often followed by surgical revisions, speech therapy, and orthodontic therapy.

Development of the Ossa Cranii

Fig. 2.1 **Bones of the skull**
Left lateral view. The skull forms a bony capsule that encloses the brain and viscera of the head. The bones of the skull are divided into two parts. The viscerocranium (orange), the facial skeleton, is formed primarily from the arcus pharyngei (see pp. 6 and 7). The neurocranium (gray), the cranial vault, is the bony capsule enclosing the brain. It is divided into two parts based on ossification (see **Fig. 2.2**). The *cartilaginous* neurocranium undergoes endochondral ossification to form the base of the skull. The *membranous* neurocranium undergoes intramembranous ossification.

Fig. 2.2 **Ossification of the ossa cranii**
Left lateral view. The bones of the skull develop either directly or indirectly from mesenchymal connective tissue. The bones of the desmocranium (gray) develop directly via intramembranous ossification of mesenchymal connective tissue. The bones of the chondrocranium (blue) develop indirectly via endochondral ossification of hyaline cartilage. *Note:* The skull base is formed exclusively by the chondrocranium. Elements formed via intramembranous and endochondral ossification may fuse to form a single bone (e.g., the elements of the ossa occipitale, temporale, and sphenoidale contributing to the skull base are cartilaginous, while the rest of the bone is membranous).

Table 2.1 **Development of the skull**

Embryonic origins		Adult bone	Ossification
Viscerocranium			
Crista neuralis, arcus pharyngei	Arcus pharyngeus primus, prominentia maxillaris	Maxilla	I
		Os nasale	I
		Os lacrimale	I
		Vomer	I
		Os palatinum	I
		Os zygomaticum	I
		Os temporale, pars tympanica	I
	Arcus pharyngeus primus, prominentia mandibularis	Mandibula	I
		Malleus	E
		Incus	E
	Arcus pharyngeus secundus	Stapes	E
		Os temporale, processus styloideus	E
		Os hyoideum, cornu minus	E
	Arcus pharyngeus tertius	Os hyoideum, cornu majus	E
Crista neuralis		Os sphenoidale, processus pterygoideus	E
Membranous neurocranium			
Crista neuralis		Os frontale	I
		Os temporale, pars squamosa	I
Paraxial mesoderma		Os ethmoidale	E
		Os sphenoidale	E
Cartilaginous neurocranium			
Crista neuralis		Os ethmoidale	E
		Os sphenoidale	E
Paraxial mesoderma		Os occipitale, pars basilaris	E
		Os temporale, pars petrosa	E

Abbreviations: I, intramembranous; E, endochondral.
Note: Tubular (long) bones undergo endochondral ossification. The clavicula is the only exception. Congenital defects of intramembranous ossification therefore affect both the skull and clavicula (cleidocranial dysostosis).

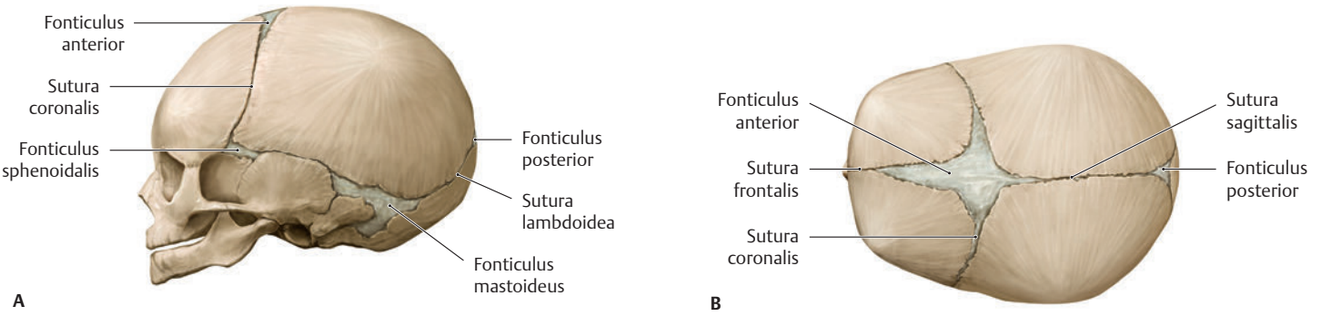


Fig. 2.3 **Suturae cranii (craniosynostoses) and fonticuli**
A Left lateral view of neonatal skull.
B Superior view of neonatal skull.
The flat cranial bones grow as the brain expands; thus the sutures between them remain open after birth. In the neonate, there are six areas (fonticuli) between the still-growing cranial bones that are occupied by unossified fibrous membrane. The fonticulus posterior provides a reference point for describing the position of the fetal head during childbirth. The fonticulus anterior provides access for drawing liquor cerebrospinalis (CSF) samples in infants (e.g., in suspected meningitis).

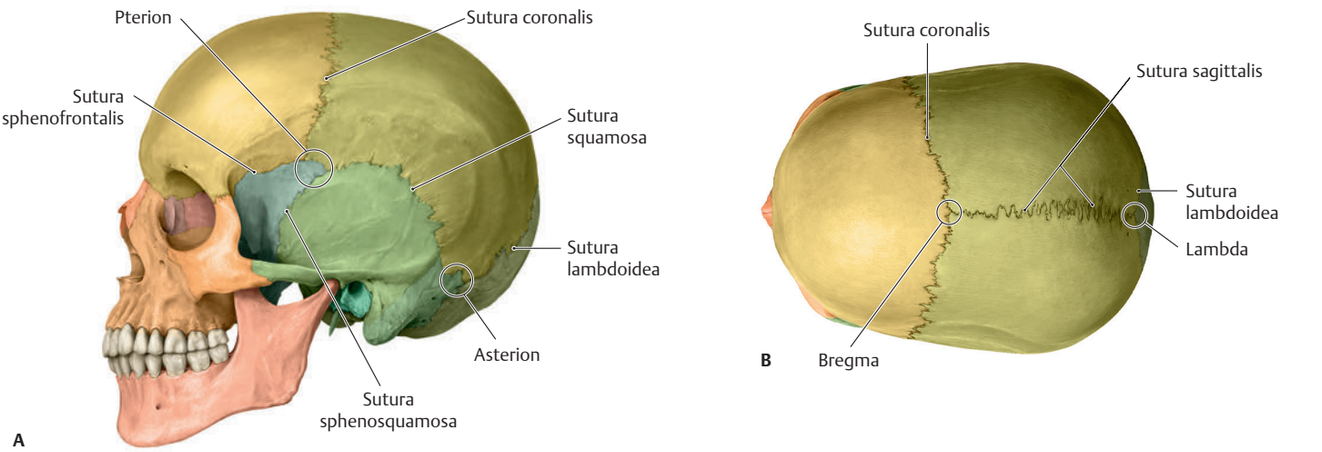


Fig. 2.4 **Sutures in the adult skull**
A Left lateral view.
B Superior view.
Synostosis (the fusion of the cranial bones along the sutures) occurs during adulthood. Although the exact times of closure vary, the order (sagittalis, coronalis, lambdoidea) does not. Closure of each fonticulus yields a particular junction (see **Table 2.2**). Premature closure of the suturae cranii produces characteristic deformities (see **Fig. 2.11**, p. 22).

Table 2.2 **Closure of suturae and fonticuli**

Fontanelle	Age at closure	Suture	Age at ossification
1 Fonticulus posterior	2–3 months (lambda)	Sutura frontalis	Childhood
2 Fonticuli sphenoidales	6 months (pterion)	Sutura sagittalis	20–30 years old
2 Fonticuli mastoidei	18 months (asterion)	Sutura coronalis	30–40 years old
1 Fonticulus anterior	36 months (bregma)	Sutura lambdoidea	40–50 years old

Skull: Lateral View

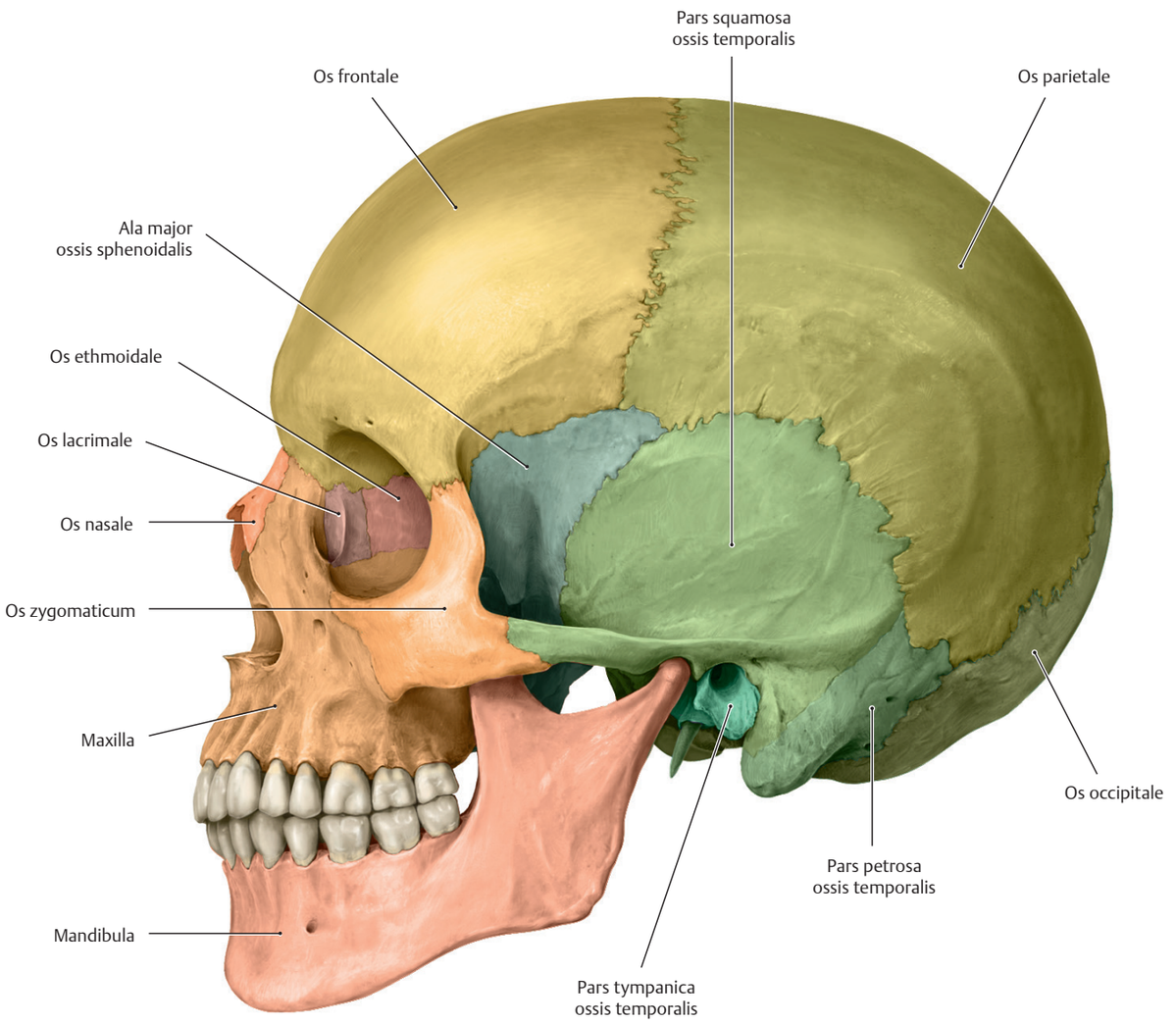


Fig. 2.5 **Ossa cranii**
Left lateral view.

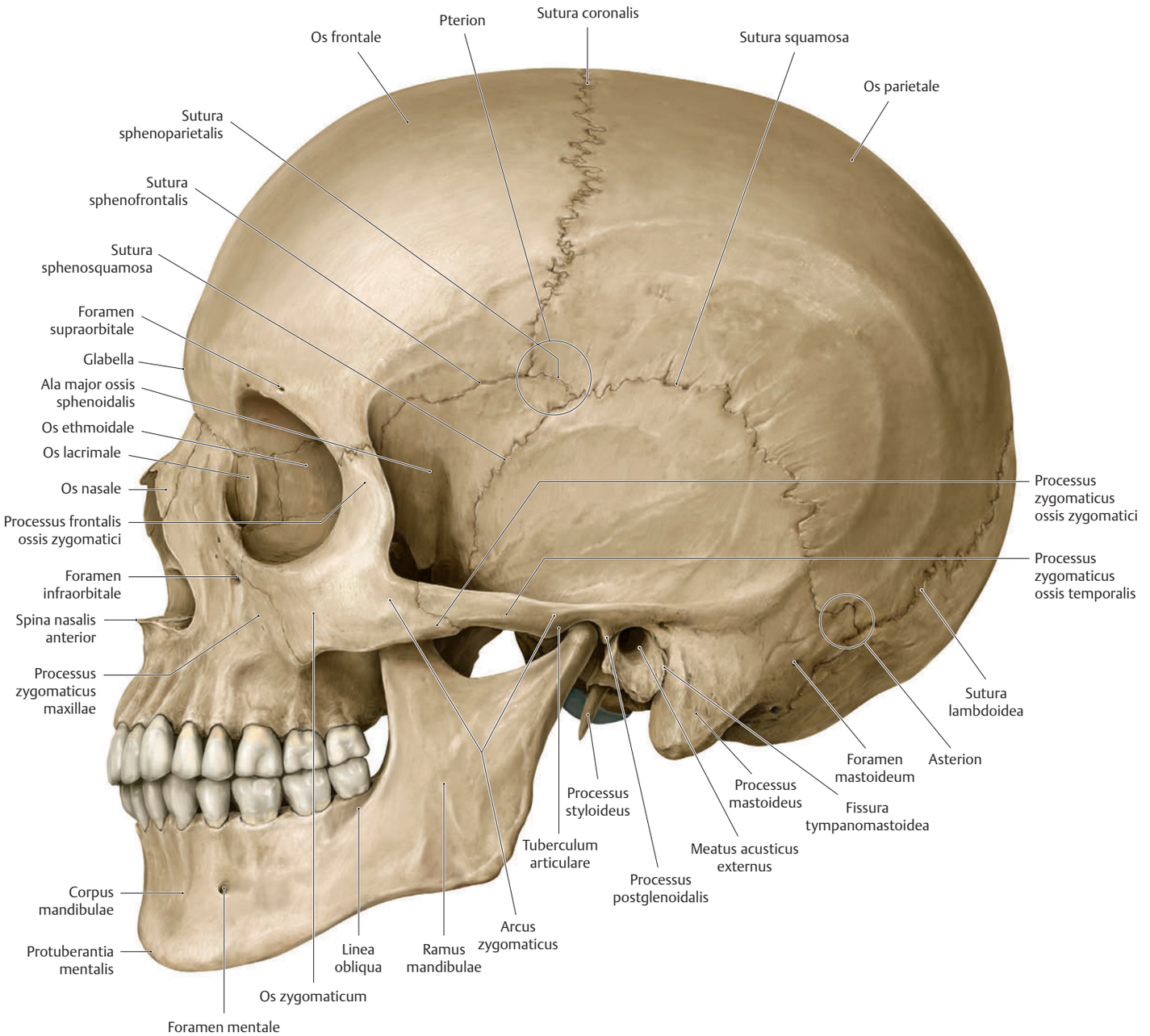


Fig. 2.6 **Skull (cranium)**
Left lateral view. This view displays the greatest number of ossa cranii (indicated by different colors in **Fig. 2.5**). The arcus zygomaticus is formed by the processus zygomaticus ossis temporalis and the processus temporalis ossis zygomatici, which are united by an oblique suture.

Skull: Anterior View

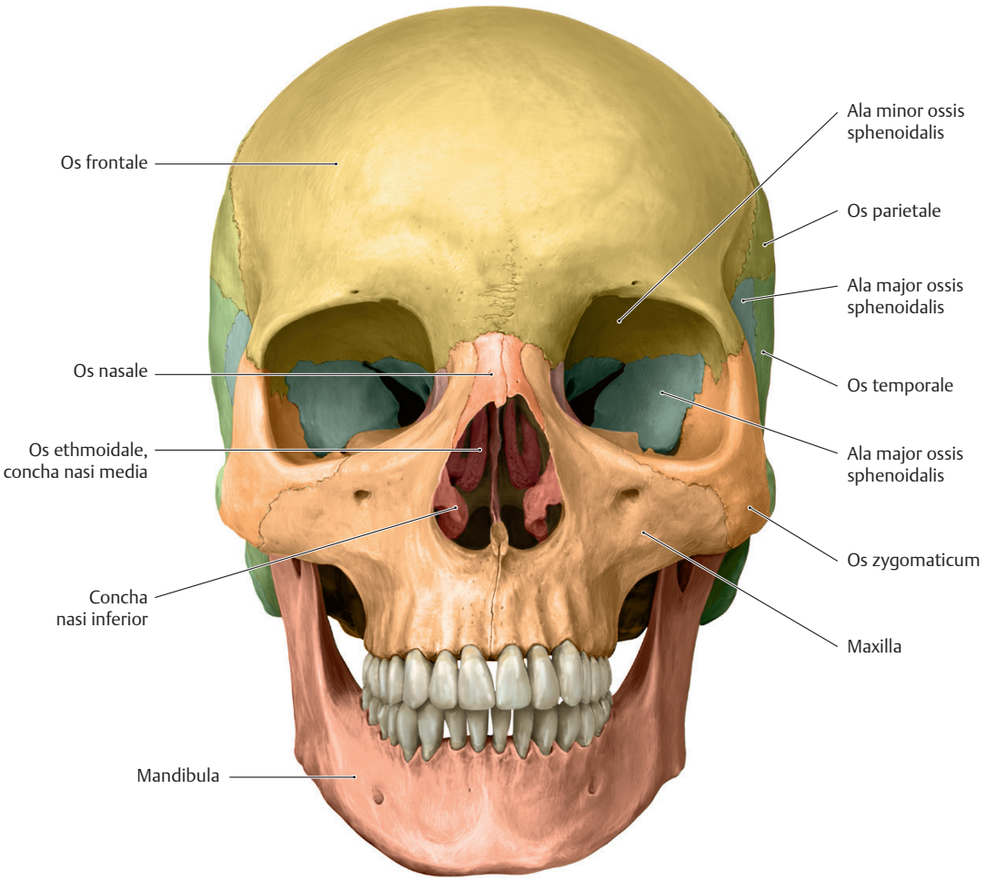


Fig. 2.7 **Ossa cranii**
Anterior view.

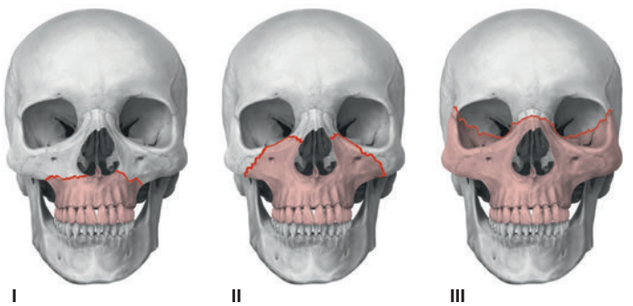


Fig. 2.8 **Le Fort classification of midfacial fractures**
The framelike construction of the facial skeleton leads to characteristic patterns of fracture lines in the midfacial region (Le Fort I, II, and III).
Le Fort I: This fracture line runs across the maxilla and above the palatum durum. The maxilla is separated from the upper facial skeleton, disrupting the integrity of the sinus maxillaris (*low transverse fracture*).
Le Fort II: The fracture line passes across the sinus maxillaris, os ethmoidale, maxilla, and os zygomaticum, creating a *pyramid fracture* that disrupts the integrity of the orbita.
Le Fort III: The facial skeleton is separated from the base of the skull. The main fracture line passes through the orbitae, and the fracture may additionally involve the ossa ethmoidalia, sinus frontales, sinus sphenoidales, and ossa zygomatica.

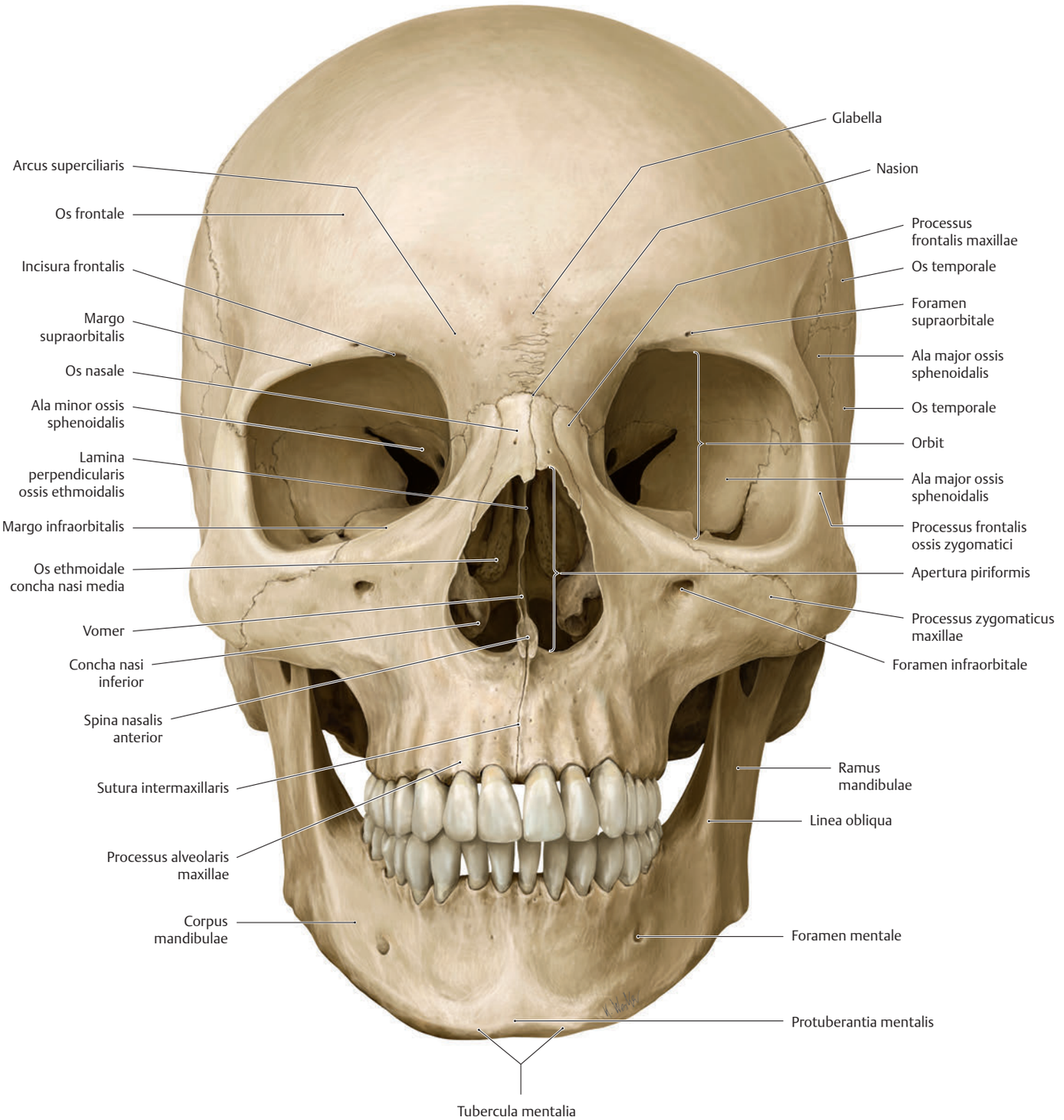


Fig. 2.9 **Skull**
Anterior view. The boundaries of the facial skeleton (viscerocranium) can be clearly appreciated in this view. The bony margins of the apertura piriformis mark the start of the respiratory tract in the skull. The cavitas nasi, like the orbitae, contains a sensory organ (the olfactory mucosa). The *sinus paranasales* are shown schematically in **Fig. 7.8,** p. 175. The anterior view of the skull also displays the three clinically important openings through which sensory nerves pass to supply the face: the foramen supraorbitale, foramen infraorbitale, and foramen mentale.

Skull: Posterior View

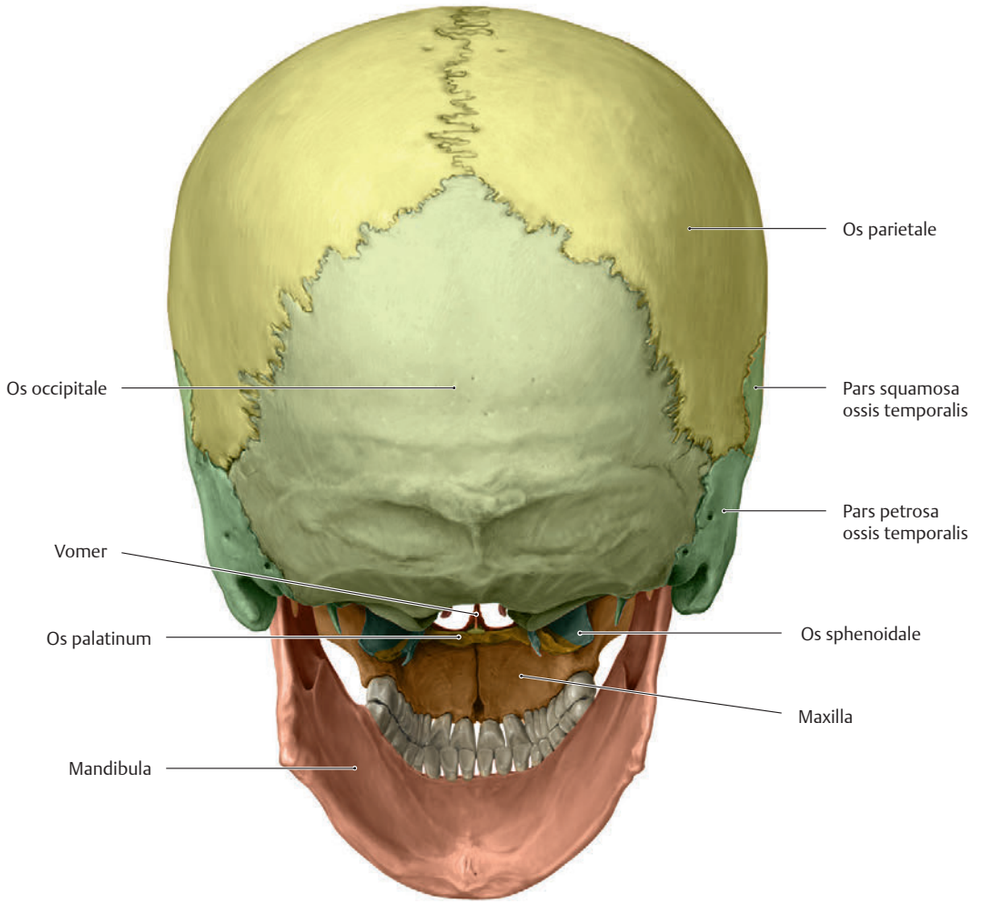


Fig. 2.10 **Ossa cranii**
Posterior view.

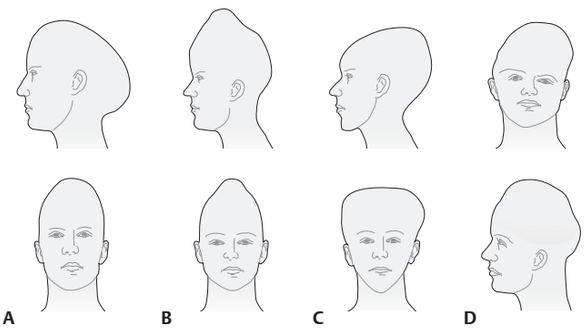


Fig. 2.11 **Premature closure of suturae cranii**
The premature closure of a sutura cranii (craniosynostosis) may lead to characteristic cranial deformities:

A Sutura sagittalis: scaphocephaly (long, narrow skull).
B Sutura coronalis: oxycephaly (pointed skull).
C Sutura frontalis: trigonocephaly (triangular skull).
D Asymmetrical suture closure, usually involving the sutura coronalis: plagiocephaly (asymmetric skull).

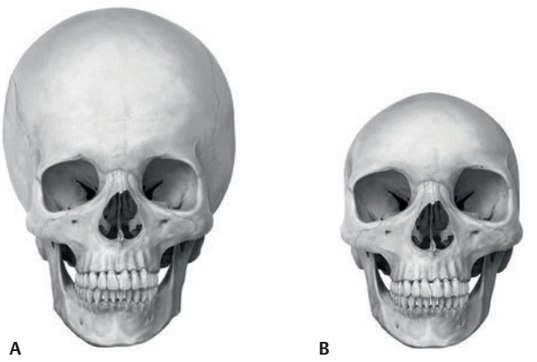


Fig. 2.12 **Hydrocephalus and microcephaly**
A **Hydrocephalus:** When the brain becomes dilated due to liquor cerebrospinalis (CSF) accumulation *before* the suturae cranii ossify, the neurocranium will expand, whereas the facial skeleton remains unchanged.
B **Microcephaly:** Premature closure of the suturae cranii results in a small neurocranium with relatively large orbitae.

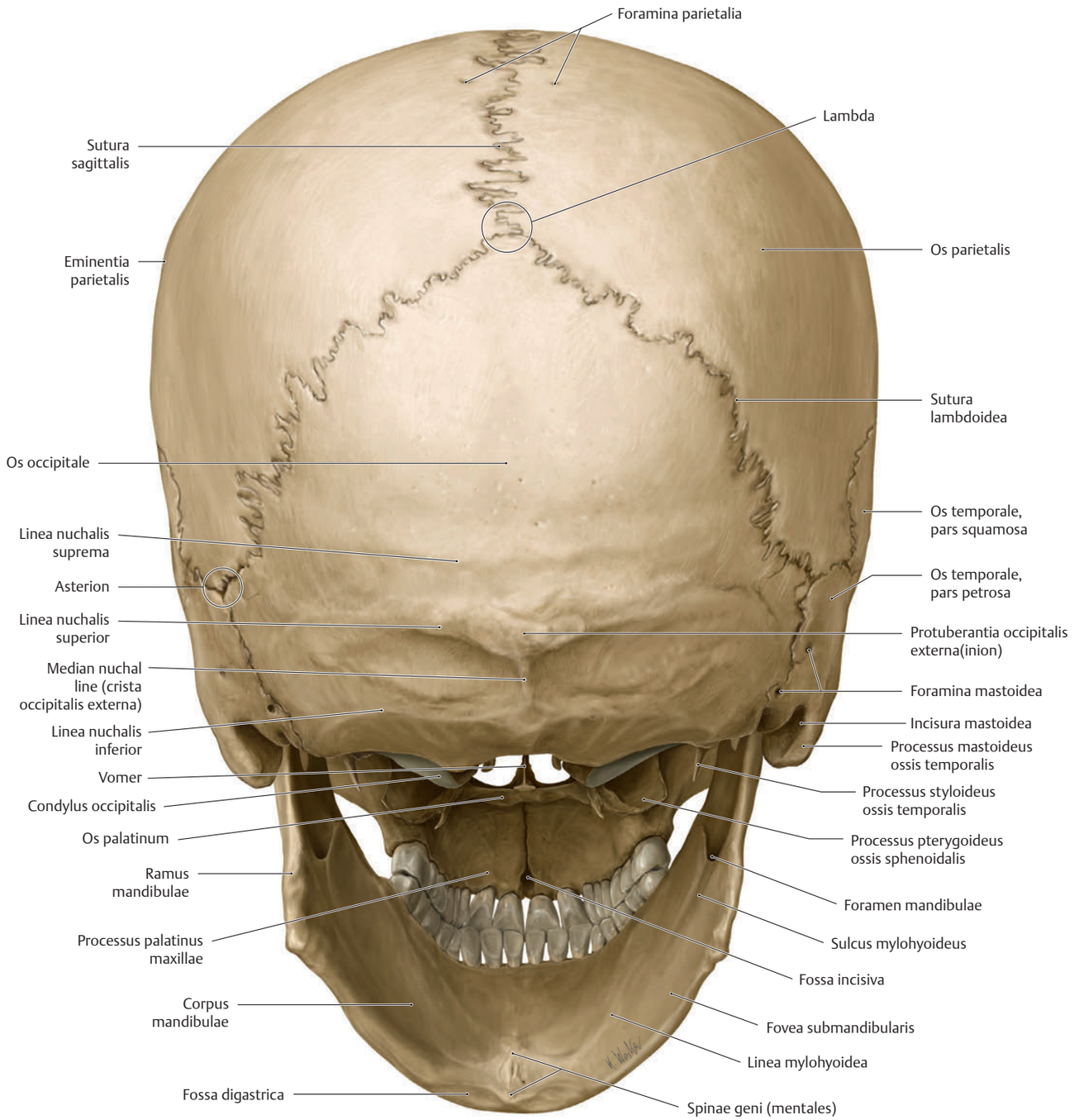


Fig. 2.13 **Skull**
Posterior view. The os occipitale, which is dominant in this view, articulates with the ossa parietalia, to which it is connected by the sutura lambdoidea. Ossa suturalia are isolated bone plates often found in the sutura lambdoidea. The suturae cranii are a special type of syndesmosis (i.e., ligamentous attachments that ossify with age). The outer surface of the os occipitale is contoured by muscular origins and insertions: the lineae nuchales inferior, superior, and suprema and crista occipitalis externa.

Calvaria

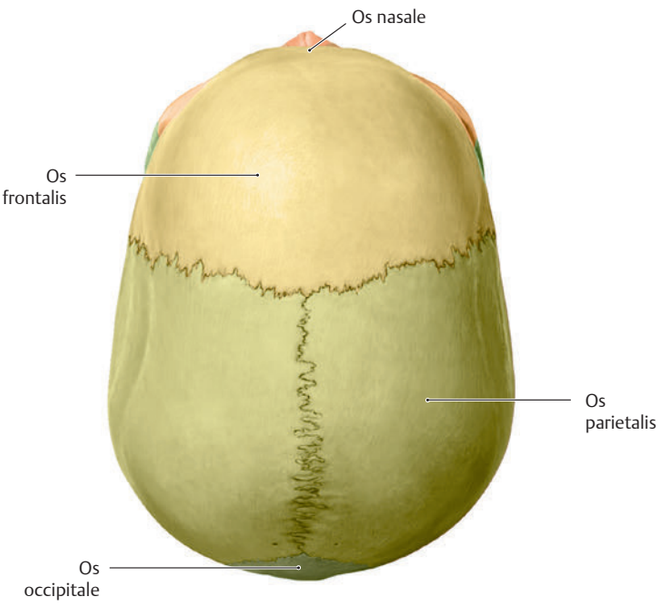


Fig. 2.14 **Bones of the calvaria**
External surface, superior view.

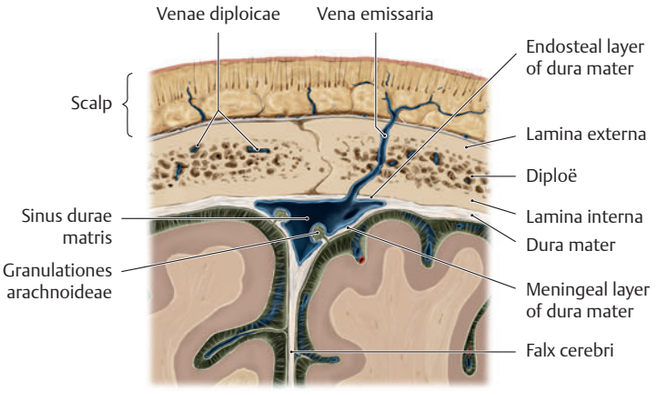


Fig. 2.15 **The scalp and calvaria**
The three-layered calvaria consists of the lamina externa, the diploë, and the lamina interna. The diploë has a spongy structure and contains red (blood-forming) bone marrow. With a plasmacytoma (malignant transformation of certain white blood cells), many small nests of tumor cells may destroy the surrounding bony trabeculae, and radiographs will demonstrate multiple lucent areas ("punched-out lesions") in the skull.

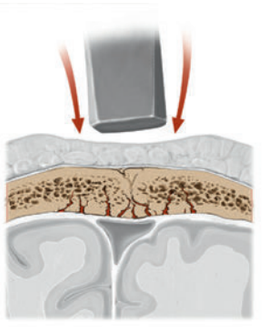


Fig. 2.16 **Sensitivity of the lamina interna to trauma**
The lamina interna of the calvaria is very sensitive to external trauma and may fracture even when the lamina externa remains intact (look for corresponding evidence on CT images).

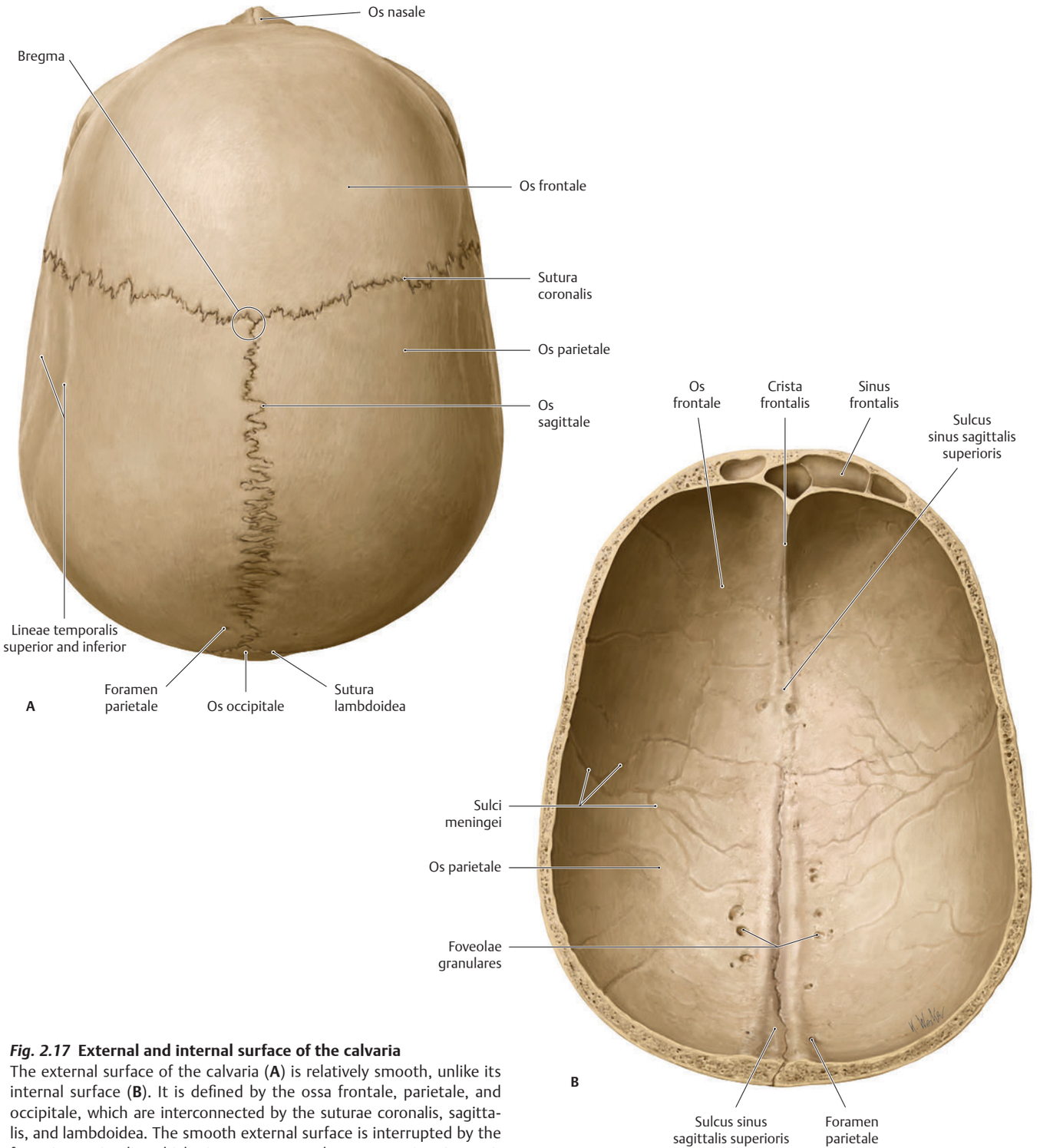


Fig. 2.17 **External and internal surface of the calvaria**
The external surface of the calvaria (**A**) is relatively smooth, unlike its internal surface (**B**). It is defined by the ossa frontale, parietale, and occipitale, which are interconnected by the suturae coronalis, sagittalis, and lambdoidea. The smooth external surface is interrupted by the foramina parietalia, which gives passage to the venae emissariae parietales (see **Fig. 3.24**, p. 67). The internal surface of the calvaria bears a number of pits and grooves:

- Foveolae granulares (small pits in the inner surface of the skull caused by saccular protrusions of the arachnoidea mater [granulationes arachnoideae] covering the encephalon)
- Groove for the sinus sagittalis superior (a sinus durae matris of the encephalon, see **Fig. 3.22**, p. 66)
- Sulci arteriosi (which mark the positions of the arterial vessels of the dura mater, such as the arteria meningea media, which supplies most of the dura mater and overlying bone)
- Crista frontalis (which gives attachment to the falx cerebri, a sickle-shaped fold of dura mater between the hemispheria cerebri).

Skull Base: Exterior

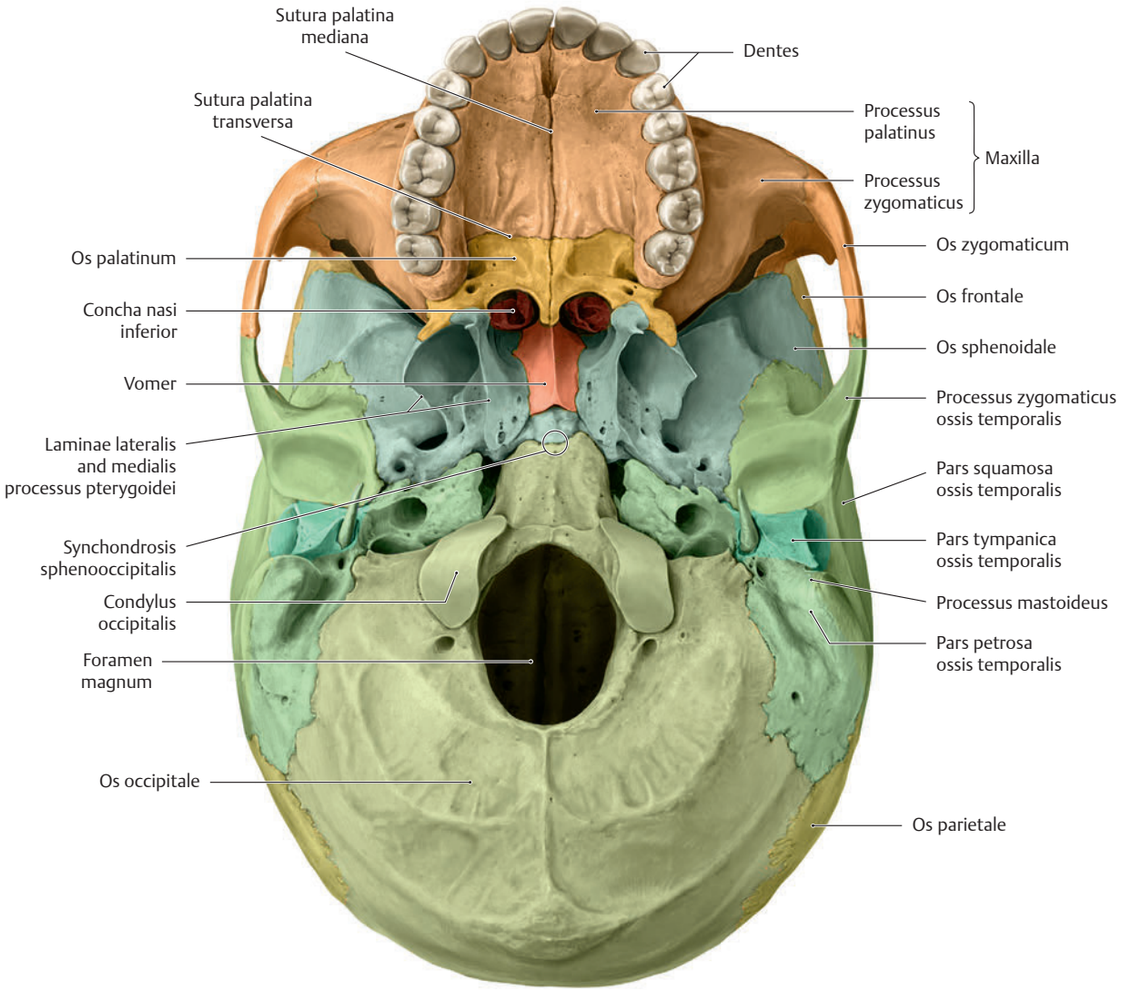


Fig. 2.18 **Bones of the skull base**
External surface, inferior view. The base of the skull is composed of a mosaic-like assembly of various bones.

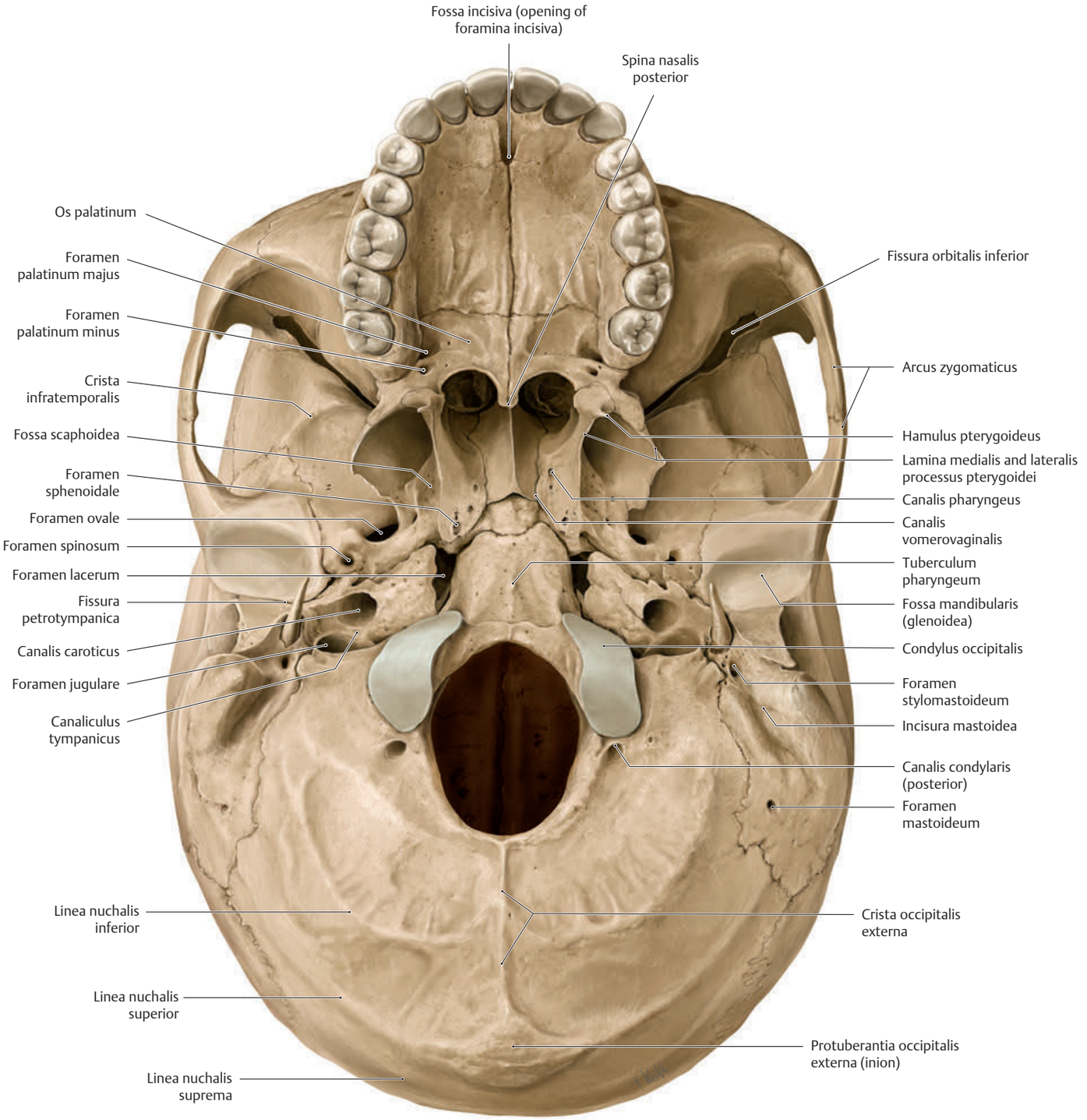


Fig. 2.19 **Skull base**
External surface, inferior view. Note the openings that transmit nerves and vessels. With abnormalities of bone growth, these openings may remain too small or may become narrowed, compressing the neurovascular structures that pass through them. The symptoms associated with these lesions depend on the affected opening. All of the structures depicted here will be considered in more detail in subsequent pages.

Skull Base: Interior

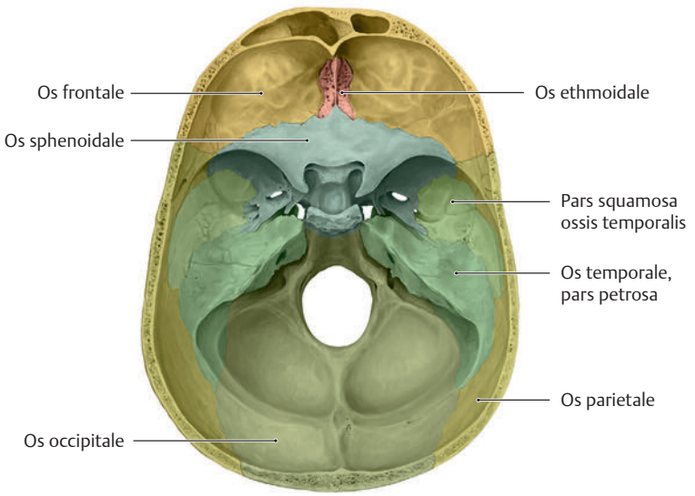


Fig. 2.20 **Bones of the skull base**
Internal surface, superior view.

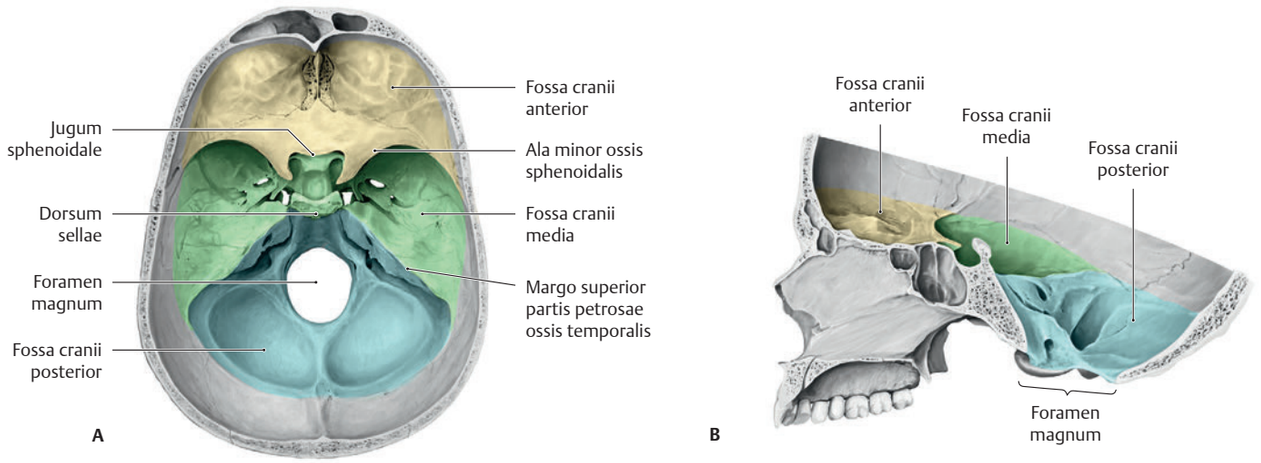


Fig. 2.21 **The fossae cranii**
A Skull base, internal surface, superior view. **B** Skull base, midsagittal section. The interior of the skull base is deepened to form three successive fossae: the fossae cranii anterior, media, and posterior. These depressions become progressively deeper in the frontal-to-occipital direction, forming a terraced arrangement that is displayed most clearly in **B**.

The fossae cranii are bounded by the following structures:

- Anterior to middle: alae minores ossis sphenoidalis and the jugum sphenoidale
- Middle to posterior: margo superior partis petrosae ossis temporalis and the dorsum sellae

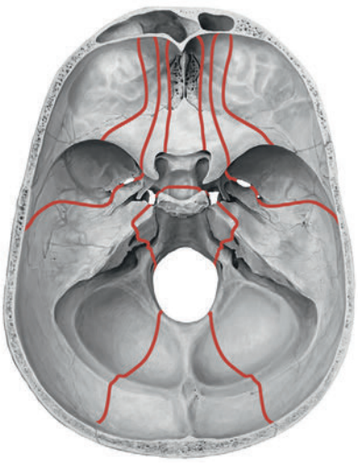


Fig. 2.22 **Common fracture lines of skull base**
Internal surface, superior view. In response to masticatory pressures and other mechanical stresses, the bones of the skull base are thickened to form "pillars" along the principal lines of force. The intervening areas that are not thickened are sites of predilection for bone fractures, resulting in the typical patterns of skull base fracture lines shown here in red. An analogous phenomenon of typical fracture lines is found in the midfacial region (see the anterior views of Le Fort fractures on p. 20).

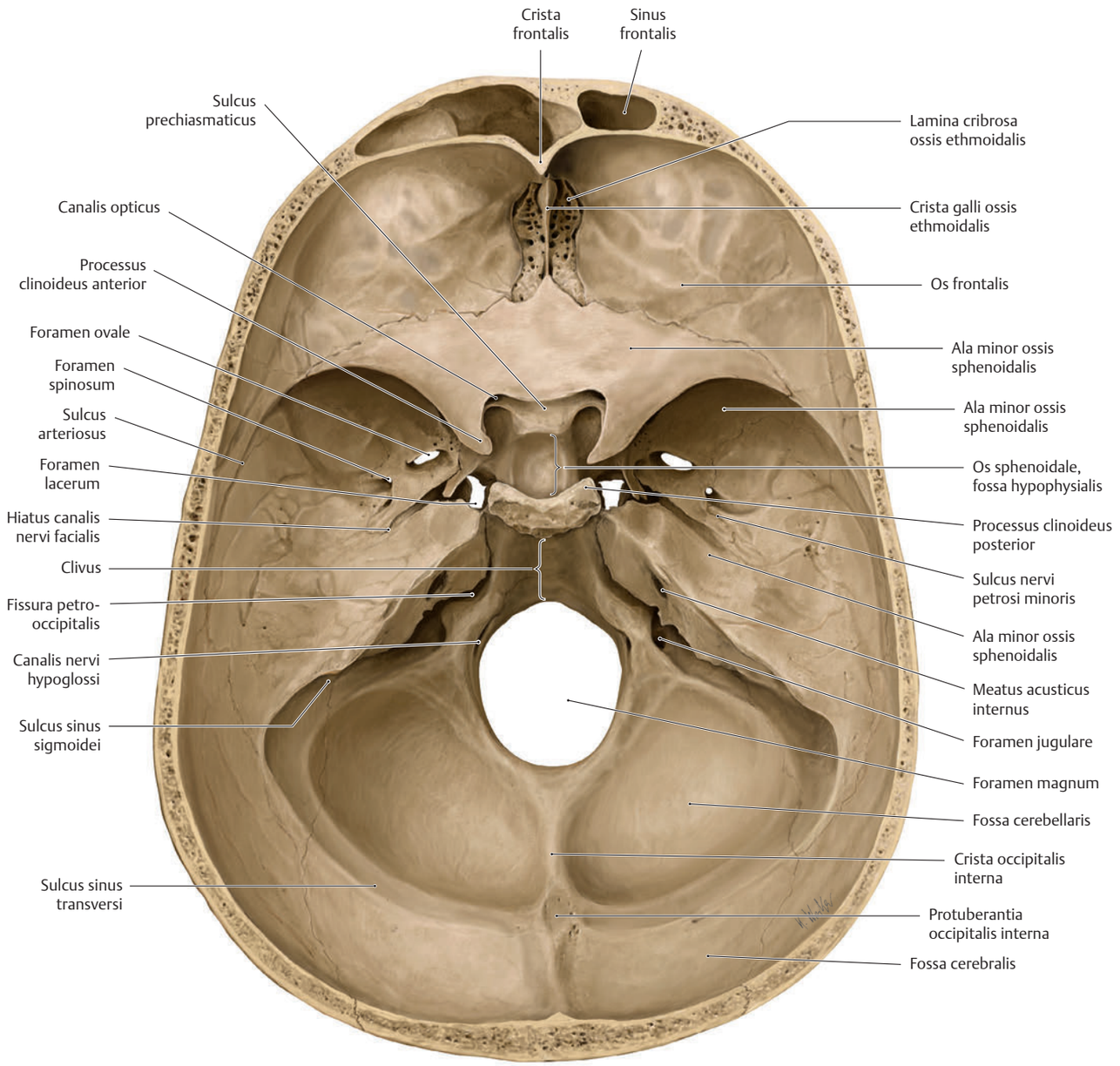


Fig. 2.23 **Skull base**
Internal surface, superior view. The openings in the interior of the base of the skull do not always coincide with the openings visible on the exterior because some neurovascular structures change direction when passing through the bone or pursue a relatively long intraosseous course. An example of this is the meatus acusticus internus, through which the nervus facialis, among other structures, passes from the interior of the skull into the pars petrosa ossis temporalis. Most of its fibers then leave the pars petrosa through the foramen stylomastoideum, which is visible from the external aspect (see **Fig.4.87**, p. 131, and **Fig. 2.45**, p. 44, for further details).

In learning the sites where neurovascular structures pass through the base of the skull, it is helpful initially to note whether these sites are located in the fossa cranii anterior, media, or posterior. The arrangement of the fossae cranii is shown in **Fig. 2.21**.

The lamina cribrosa ossis ethmoidalis connects the cavitas nasi with the fossa cranii anterior and is perforated by numerous foramina for the passage of the fila olfactoria (see **Fig. 7.22**, p. 180). *Note:* Because the bone is so thin in this area, a frontal head injury may easily fracture the lamina cribrosa and lacerate the dura mater, allowing liquor cerebrospinalis (CSF) to enter the nose. This poses a risk of meningitis, as bacteria from the nonsterile cavitas nasi may enter the sterile CSF.

Os Sphenoidale

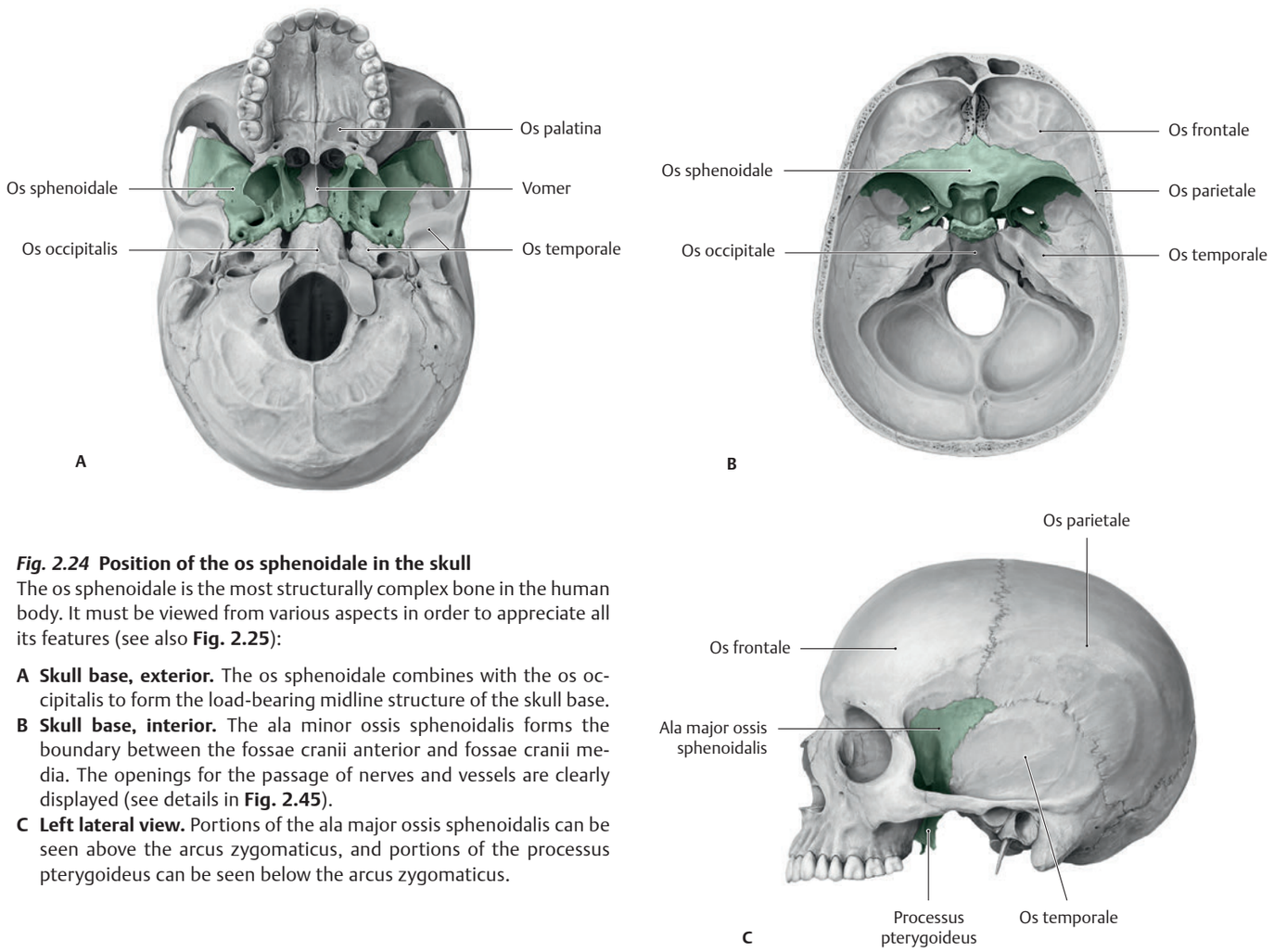


Fig. 2.24 **Position of the os sphenoidale in the skull**
The os sphenoidale is the most structurally complex bone in the human body. It must be viewed from various aspects in order to appreciate all its features (see also **Fig. 2.25**):

A **Skull base, exterior.** The os sphenoidale combines with the os occipitalis to form the load-bearing midline structure of the skull base.

B **Skull base, interior.** The ala minor ossis sphenoidalis forms the boundary between the fossae cranii anterior and fossae cranii media. The openings for the passage of nerves and vessels are clearly displayed (see details in **Fig. 2.45**).

C **Left lateral view.** Portions of the ala major ossis sphenoidalis can be seen above the arcus zygomaticus, and portions of the processus pterygoideus can be seen below the arcus zygomaticus.

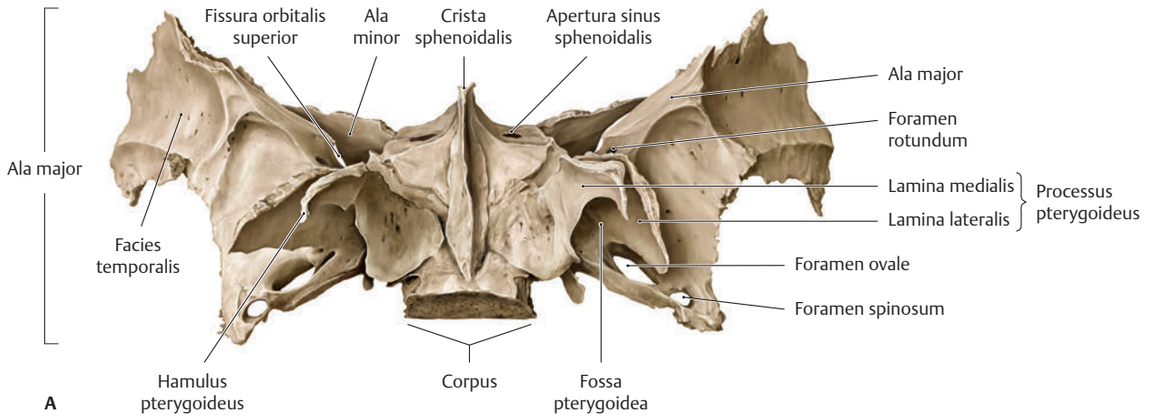
Fig. 2.25 **Isolated os sphenoidale**

A **Inferior view** (its position in situ is shown in **Fig. 2.24**). This view demonstrates the laminae medialis and lateralis processus pterygoidei. Between them is the fossa pterygoidea, which is occupied by the musculus pterygoideus medialis. The foramen spinosum and foramen ovale provide pathways through the base of the skull (see also in **C**).

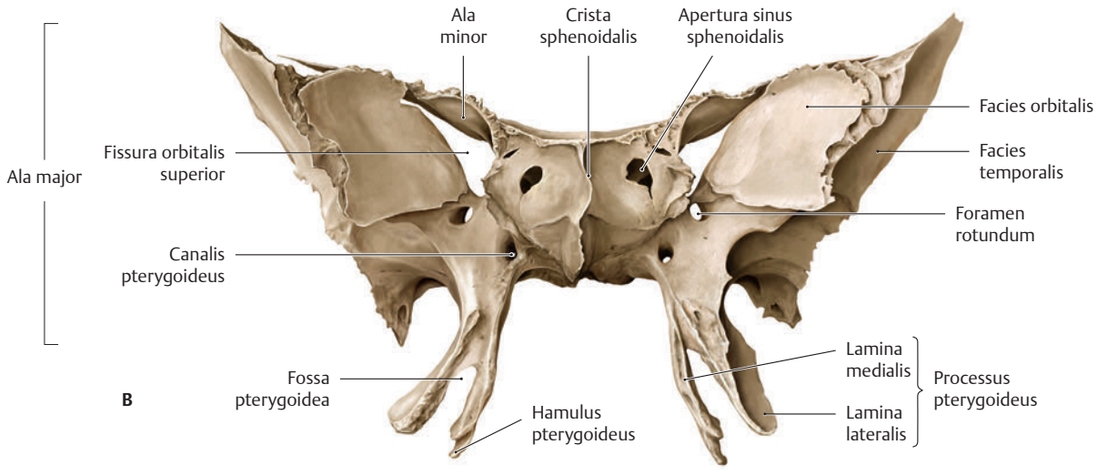
B **Anterior view.** This view illustrates why the os sphenoidale was originally called the os sphecoidale (“wasp bone”) before a transcription error turned it into the os sphenoidale (“wedge-shaped”). The aperturae sinus sphenoidalis on each side resemble the eyes of the wasp, and the processus pterygoidei of the os sphenoidale form its dangling legs, between which are the fossae pterygoideae. This view also displays the fissura orbitalis superior, which connects the fossa cranialis media with the orbita on each side. The two sphenoid sinuses are separated by an internal septum (see **Fig. 7.11**, p. 175).

C **Superior view.** The superior view displays the sella turcica, whose central depression, the fossa hypophysialis, contains the hypophysis (glandula pituitaria). The foramen spinosum, foramen ovale, and foramen rotundum can be identified.

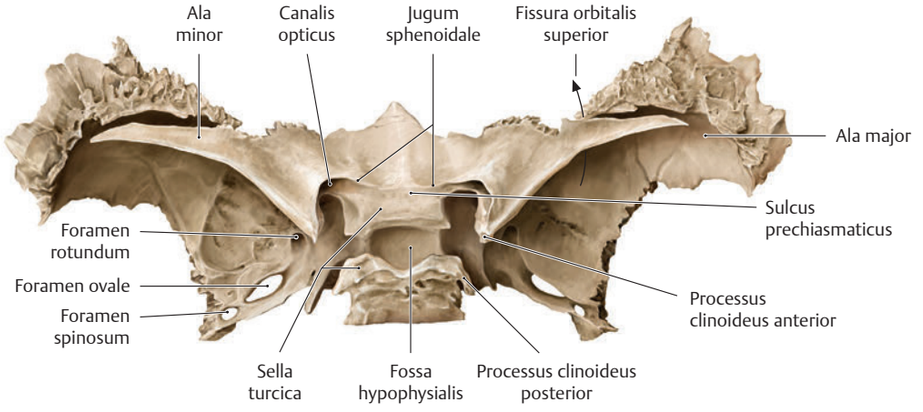
D **Posterior view.** The fissura orbitalis superior is seen clearly in this view, whereas the canalis opticus is almost completely obscured by the processus clinoideus anterior. The foramen rotundum is open from the fossa cranii media to the fossa pterygopalatina of the skull (the foramen spinosum is not visible in this view; compare with **A**). Because the ossa sphenoidale and occipitale fuse together during puberty (“tribasilar bone”), a sutura is no longer present between the two bones. The cancellous trabeculae are exposed and have a porous appearance.


Ala major
Fissura orbitalis superior
Ala minor
Crista sphenoidalis
Apertura sinus sphenoidalis
Ala major
Foramen rotundum
Lamina medialis
Lamina lateralis
Processus pterygoideus
Facies temporalis
Foramen ovale
Foramen spinosum
Hamulus pterygoideus
Corpus
Fossa pterygoidea

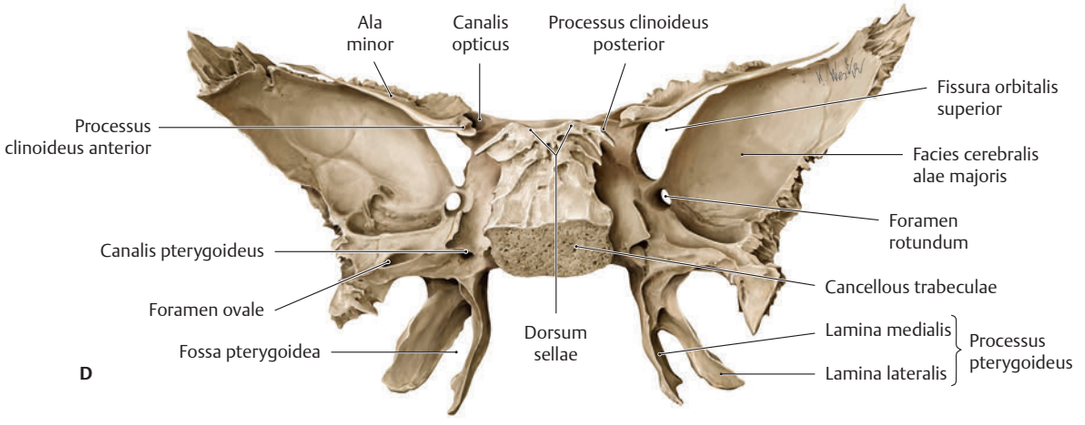
A


Ala major
Ala minor
Crista sphenoidalis
Apertura sinus sphenoidalis
Facies orbitalis
Fissura orbitalis superior
Facies temporalis
Foramen rotundum
Canalis pterygoideus
Lamina medialis
Processus pterygoideus
Lamina lateralis
Fossa pterygoidea
Hamulus pterygoideus

B


Ala minor
Canalis opticus
Jugum sphenoidale
Fissura orbitalis superior
Ala major
Sulcus prechiasmaticus
Foramen rotundum
Foramen ovale
Foramen spinosum
Processus clinoideus anterior
Sella turcica
Fossa hypophysialis
Processus clinoideus posterior

C


Ala minor
Canalis opticus
Processus clinoideus posterior
Fissura orbitalis superior
Processus clinoideus anterior
Facies cerebralis alae majoris
Foramen rotundum
Canalis pterygoideus
Cancellous trabeculae
Foramen ovale
Dorsum sellae
Lamina medialis
Processus pterygoideus
Fossa pterygoidea
Lamina lateralis

D

Os Temporale

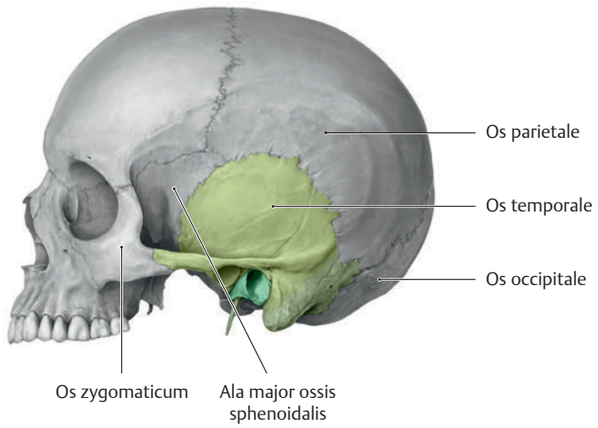


Fig. 2.26 **Position of the os temporale in the skull**
Left lateral view. The os temporale is a major component of the base of the skull. It forms the capsule for the auditory and vestibular apparatus and bears the fossa mandibularis of the articulatio temporomandibularis (TMJ).

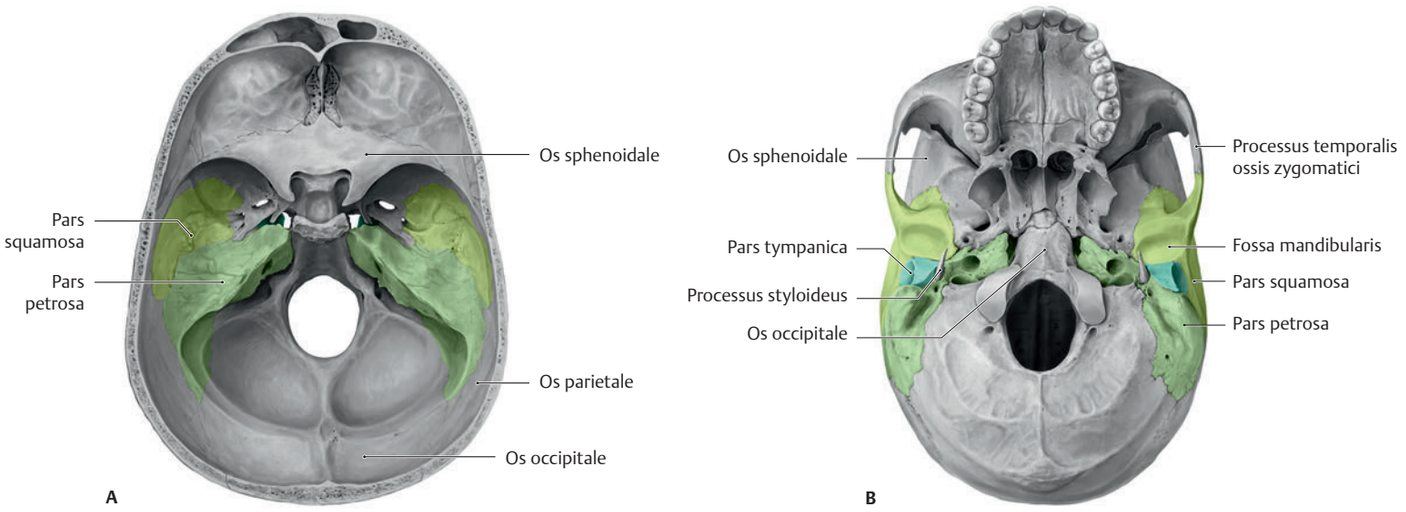


Fig. 2.27 **Os temporale in the skull**
A Internal view. **B** Inferior view.
The os temporale develops from four centers that fuse to form a single bone:

- The *pars squamosa* (light green) includes the articular fossa (fossa mandibularis) of the articulatio temporomandibularis (TMJ).
- The *pars petrosa* (pale green) contains the auditory and vestibular apparatus.
- The *pars tympanica* (darker green) forms large portions of the meatus acusticus externus.
- The *processus styloideus* develops from cartilage derived from the arcus pharyngeus secundus and is a site of muscle attachment.

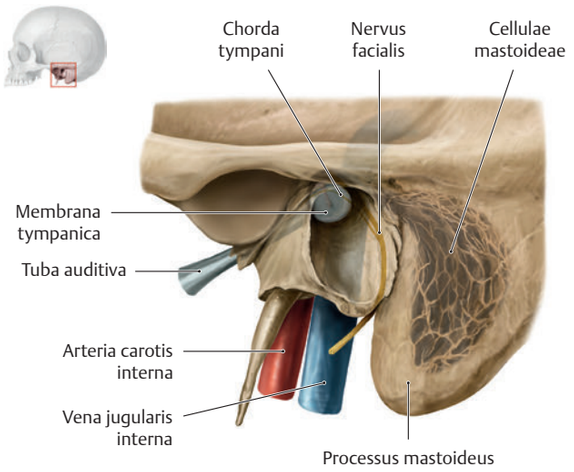


Fig. 2.28 **Projection of clinically important structures onto the left os temporale**
The membrana tympanica is shown translucent in this lateral view. Because the pars petrosa contains the auris media and interna and the membrana tympanica, a knowledge of its anatomy is of key importance in otological surgery. The internal surface of the pars petrosa has openings (see **Fig. 2.29**) for the passage of the pars petrosa, arteria carotis interna, and vena jugularis interna. A fine nerve, the chorda tympani, passes through the cavitas tympani and lies medial to the membrana tympanica. The chorda tympani arises from the nervus facialis, which is susceptible to injury during surgical procedures (see p. 131). The processus mastoideus of the pars petrosa forms air-filled chambers, the cellulae mastoideae, that vary greatly in size. Because these chambers communicate with the auris media, which in turn communicates with the pars nasalis pharyngis via the tuba auditiva, bacteria in the pars nasalis pharyngis may pass up the tuba auditiva and gain access to the auris media. From there they may pass to the cellulae mastoideae and finally enter the cavitas cranii, causing meningitis.

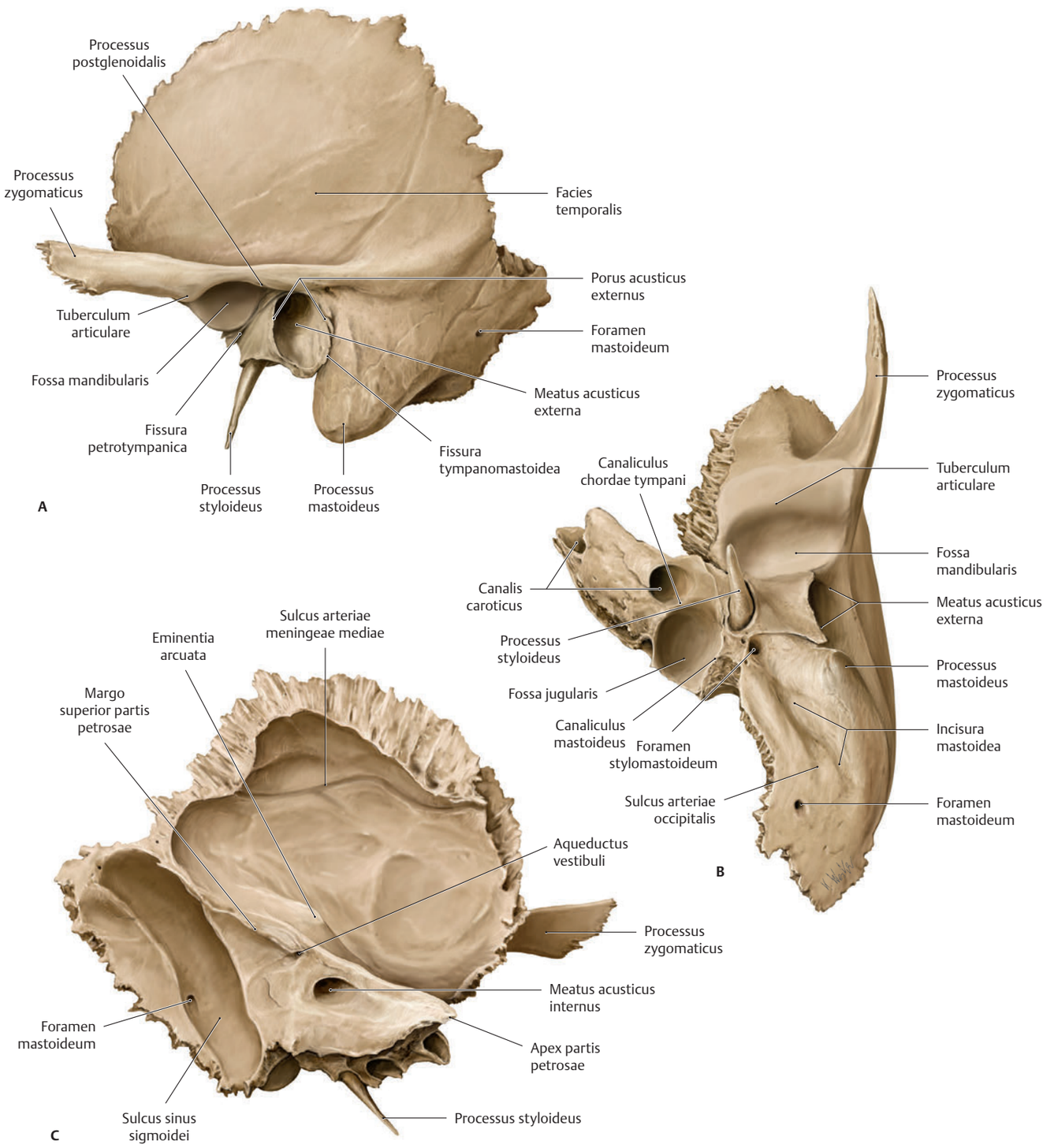


Fig. 2.29 **Left os temporale**

A **Lateral view.** A vena emissaria passes through the foramen mastoideum (external orifice shown in **A**, internal orifice in **C**), and the chorda tympani passes through the medial part of the fissura petrotympanica. The processus mastoideus develops gradually in life due to traction from the musculus sternocleidomastoideus and is pneumatized from the inside (see **Fig. 2.28**).

B **Inferior view.** The shallow articular fossa of the articulatio temporomandibularis, the fossa mandibularis, is clearly seen from the inferior view. The nervus facialis emerges from the base of the skull through the foramen stylomastoideum. The initial part of the bulbus superior venae jugularis is adherent to the fossa jugularis, and the arteria carotis interna passes through the canalis caroticus to enter the skull.

C **Medial view.** This view displays the internal orifice of the foramen mastoideum and the meatus acusticus internus. The nervus facialis and nervus vestibulocochlearis are among the structures that pass through the meatus acusticus internus to enter the pars petrosa. The part of the pars petrosa shown here is also called the *petrous pyramid*, whose apex (often called the apex partis petrosae) lies on the interior of the base of the skull.

Os Occipitale & Os Ethmoidale

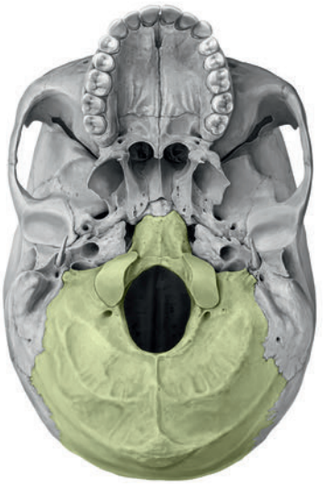
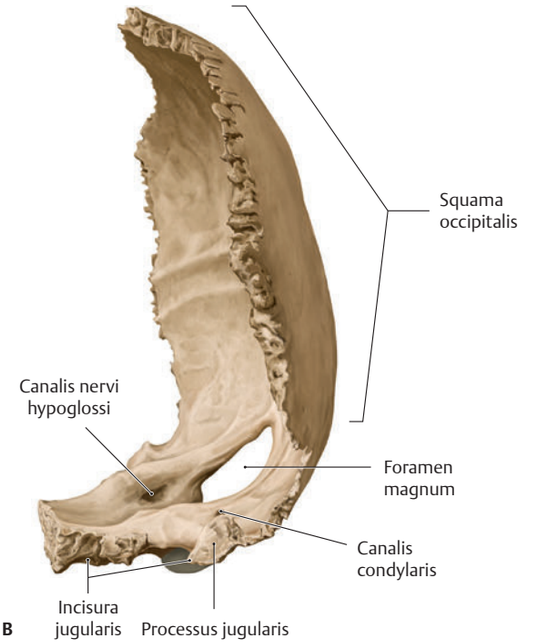
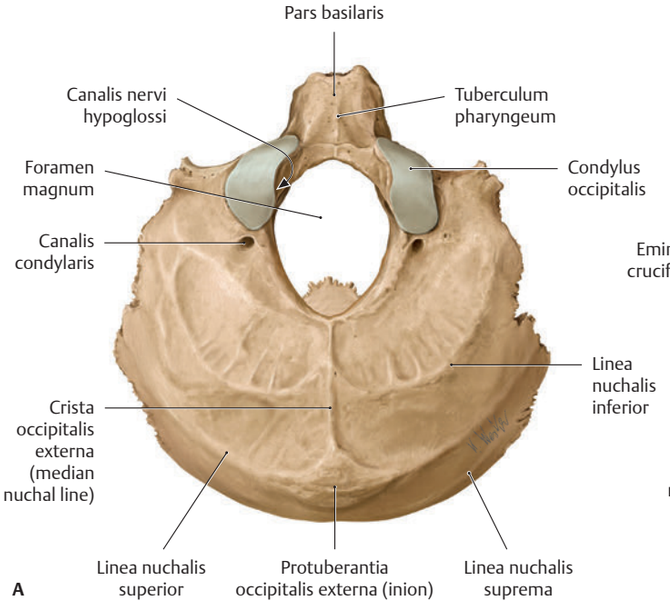


Fig. 2.30 **Position of the os occipitale in the exterior skull base**
Inferior view.





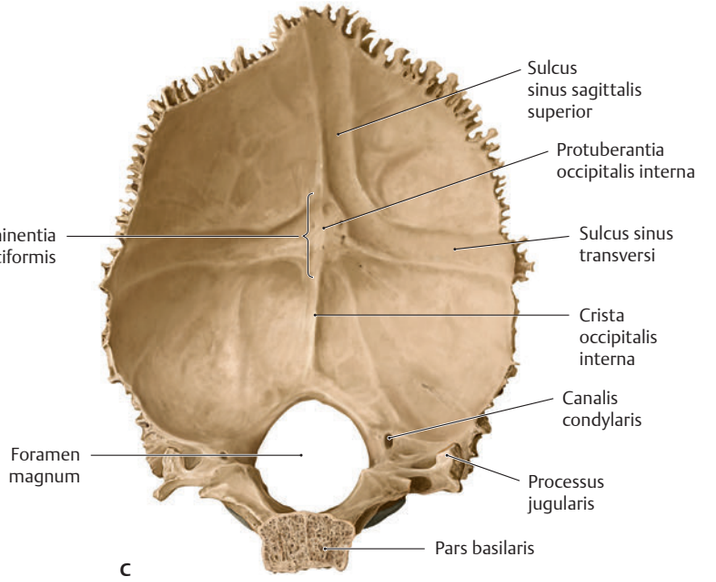


Fig. 2.31 **Isolated os occipitale**

A Inferior view. This view shows the pars basilaris of the os occipitale, whose anterior portion is fused to the os sphenoidale. The canalis condylaris terminates posterior to the condyli occipitales, and the canalis nervi hypoglossi passes superior and opens anterior to the condyli occipitales. The canalis condylaris is a venous channel that begins in the sinus sigmoideus and ends in the vena occipitalis. The canalis nervi hypoglossi contains a venous plexus in addition to the nervus hypoglossus (CN XII). The tuberculum pharyngeum gives attachment to the raphe pharyngis, and the protuberantia occipitalis externalis provides a palpable bony landmark on the occiput.

B Left lateral view. The extent of the squama occipitalis, which lies above the foramen magnum, is clearly appreciated in this view. The internal openings of the canalis condylaris and canalis nervi hypoglossi are visible along with the process jugularis, which forms part of the wall of the foramen jugulare (see p. 27).

C Internal surface. The grooves for the sinus durae matris of the brain can be identified in this view. The eminentia cruciformis overlies the confluens sinuum. The configuration of the eminence shows that in some cases the sinus sagittalis drains predominantly into the left sinus transversus.

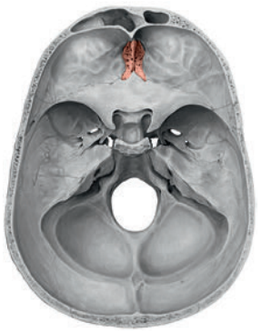


Fig. 2.32 **Position of the os ethmoidale in the interior skull base**
Superior view. The superior part of the os ethmoidale forms part of the fossa cranii anterior, and its inferior portions contribute structurally to the cavitates nasi and orbita. The os ethmoidale is bordered by the ossa frontale and sphenoidale.

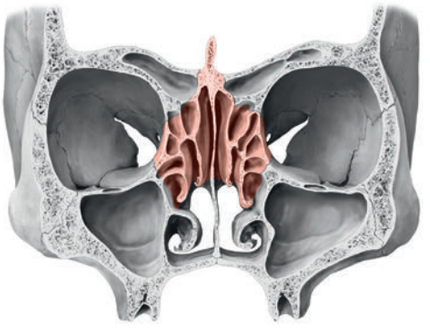


Fig. 2.33 **Position of the os ethmoidale in the facial skeleton**
Anterior view. The os ethmoidale is the central bone of the nose and sinus paranasales. It also forms the medial wall of each orbita.

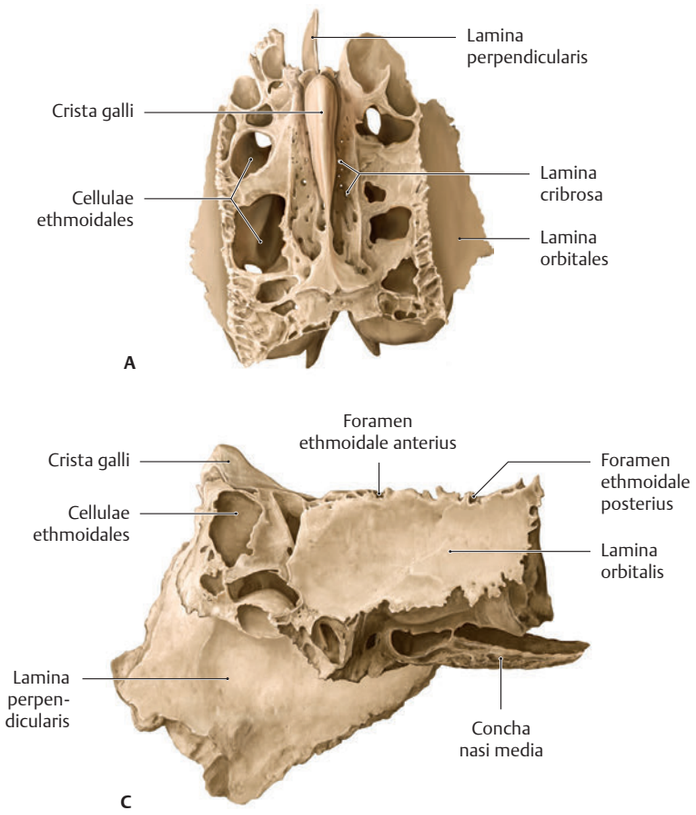


Fig. 2.34 **Isolated os ethmoidale**

A Superior view. This view demonstrates the crista galli, which gives attachment to the falx cerebri and the horizontally directed lamina cribrosa. The lamina cribrosa is perforated by foramina through which the fila olfactoria pass from the cavitas nasi into the fossa cranii anterior (see **Fig. 7.22**, p. 180). With its numerous foramina, the lamina cribrosa is a mechanically weak structure that fractures easily in response to trauma. This type of fracture is manifested clinically by CSF leakage from the nose ("runny nose" in a patient with head injury).

B Anterior view. The anterior view displays the midline structure that separates the two cavitates nasi: the lamina perpendicularis. Note also the concha nasi media, which is part of the os ethmoidale (of the conchae, only the concha nasi inferior is a separate bone), and the cellulae ethmoidales, which are clustered on both sides of the conchae nasi mediae.

C Left lateral view. Viewing the bone from the left side, we observe the lamina perpendicularis and the opened cellulae ethmoidales anteriores. The orbita is separated from the cellulae ethmoidales by a thin sheet of bone called the lamina orbitalis.

D Posterior view. This is the only view that displays the processus uncinatus, which is almost completely covered by the concha nasi media when in situ. It partially occludes the entrance to the sinus maxillaris, the hiatus semilunaris, and it is an important landmark during endoscopic surgery of the sinus maxillaris. The narrow depression between the concha nasi media and processus uncinatus is called the infundibulum ethmoidale. The sinus frontalis, sinus maxillaris, and cellulae ethmoidales anteriores open into this "funnel." The concha nasi superior is located at the posterior end of the os ethmoidale.

Os Zygomaticum & Os Nasale

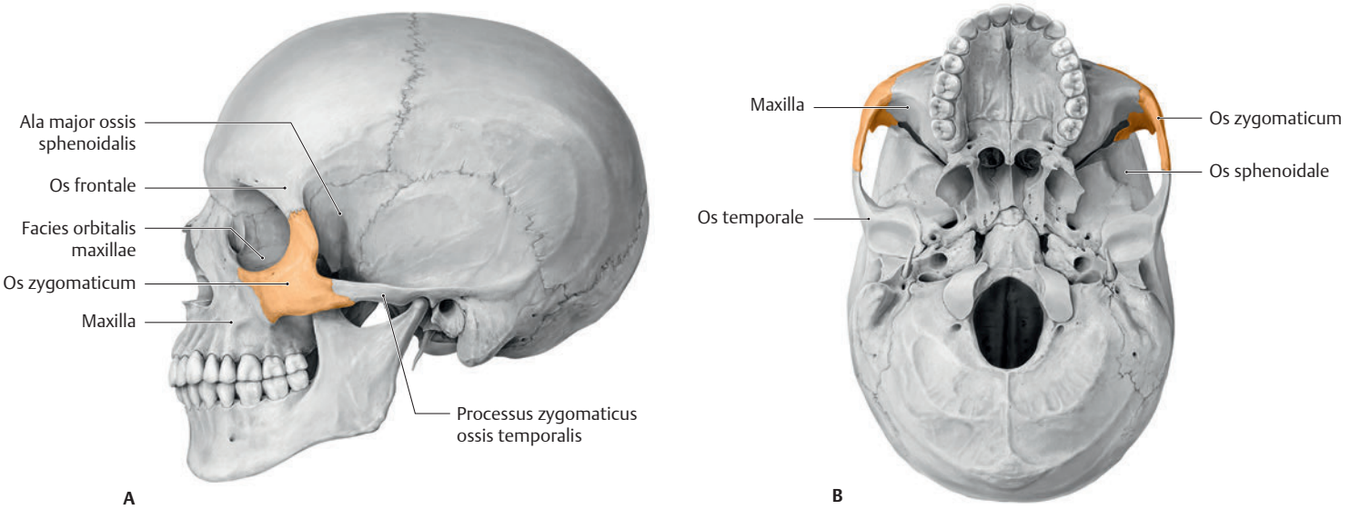


Fig. 2.35 **Os zygomaticum in the skull**
A Left lateral view. **B** Inferior view.
The os zygomaticum, or zygoma, is important in determining the width and morphology of the face and is a major buttress between the maxilla and the skull. In addition, it forms a significant portion of the floor and lateral walls of the orbita. The zygoma contains foramina that transmit the zygomaticofacial and zygomaticotemporal arteries and the nervi zygomaticofacialis and zygomaticotemporalis (from the nervus maxillaris [CN V_2]). Muscles that attach along the arcus zygomaticus include the musculus masseter, musculus zygomaticus major, and some fibers of the fascia temporalis. The tuberculum marginale, which is the attachment site for the lateral canthal tendon, is located on the zygoma. This tendon is crucial in maintaining the contour of the eye.

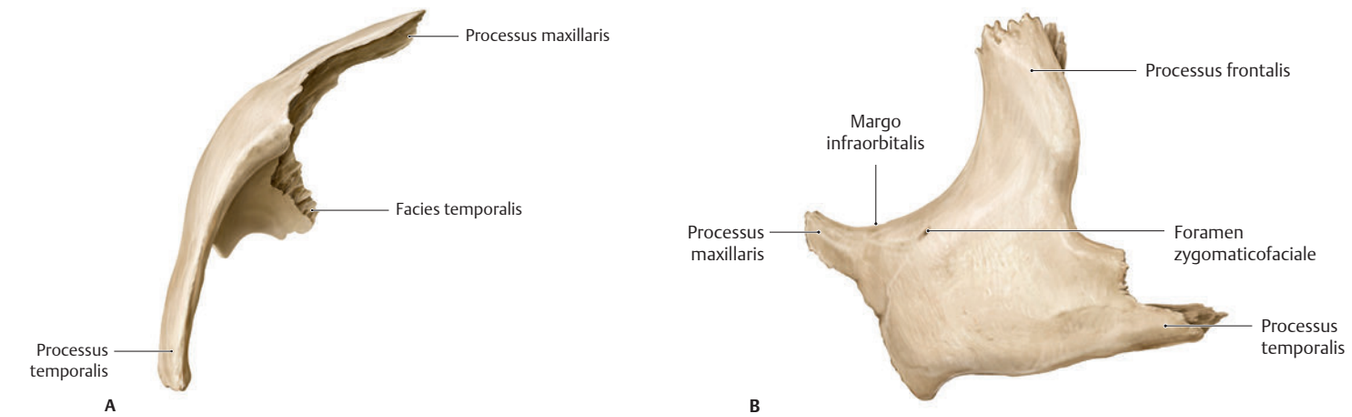


Fig. 2.36 **Isolated os zygomaticum**
A Inferior view. **B** Left lateral view.
The zygoma is a substantial bone but its prominent position on the face leaves it vulnerable to fracture following trauma. Trauma that transmits minimal force to the zygoma may cause a non-displaced fracture at the suture lines. Greater force, for example, following a motor vehicle accident, will result in displacement of the bone and involvement of the orbital rim and floor, the sutura zygomaticofrontalis, the zygomaticomaxillary buttress, and the arcus zygomaticus. Symptoms of zygoma fracture include pain, facial bruising and swelling, a flattened malar eminence, diplopia (double vision), trismus (lock jaw), and altered mastication (due to masseteric spasm or interference of the normal mechanism of the processus coronoideus by bony fragments), loss of sensation below the orbit (due to nervus infraorbitalis involvement), and ipsilateral epistaxis (nosebleed) (due to laceration of the mucosa of the sinus maxillaris). Nondisplaced fractures do not require treatment. Displaced fractures commonly require open reduction and fixation, with reconstruction of the orbita. Displacement of the arcus zygomaticus may be reduced by the Gillies technique, in which an incision is made over the musculus temporalis and an instrument is slid under the arch and hooked and the arch is elevated into its normal position.

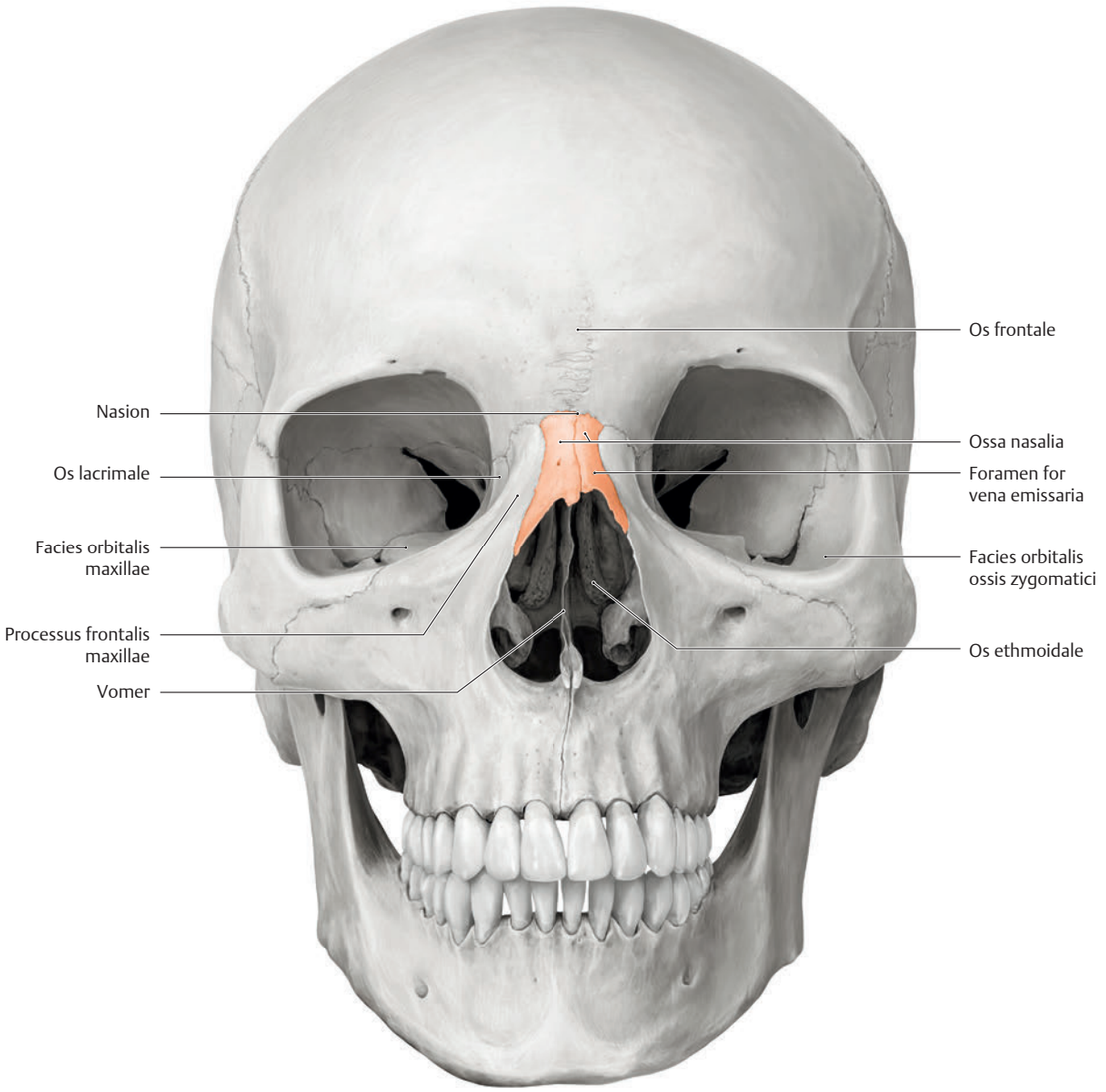


Fig. 2.37 **Os nasale in the skull**
Anterior view.
Fractures of the ossa nasalia are common following facial trauma, for example, motor vehicle accidents, sports injuries, or fights. This is due both to the prominence of the nose and the fragility of the ossa nasalia. Symptoms of nasal fractures include pain, bruising, swelling, epistaxis (nosebleeds), and deformity of the nose. The patient may also experience difficulty breathing. Minor nasal fractures require no treatment while those that cause deformity will require manual realignment. More severe nasal fractures (for example, those involving the septum nasi or other facial bones) will require surgery.

Maxilla & Palatum Durum

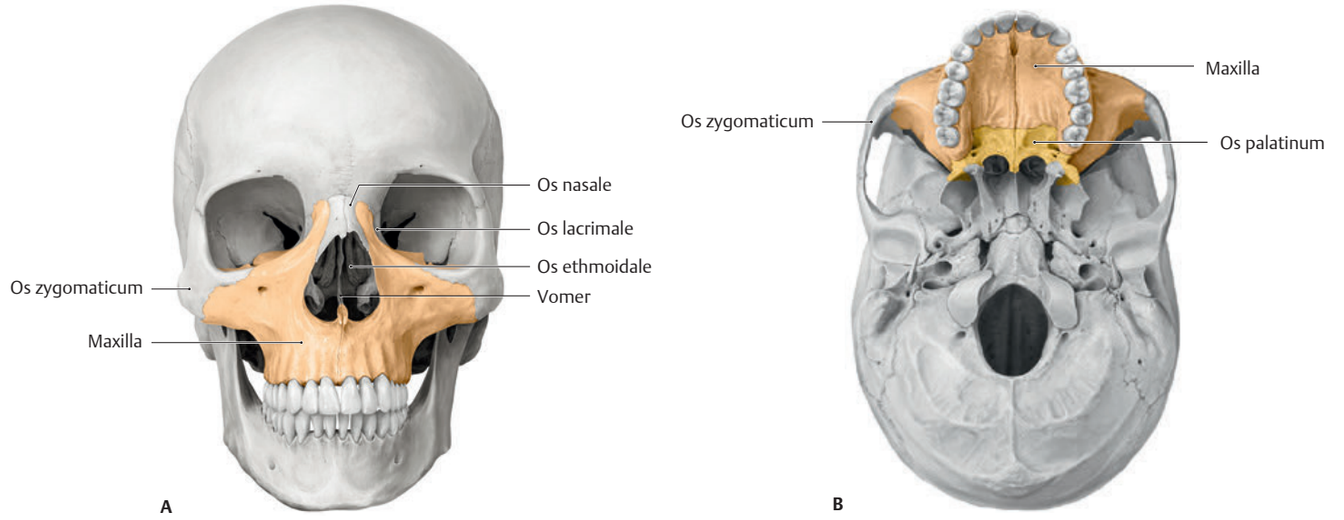


Fig. 2.38 **Maxilla and palatum durum in skull**
A Anterior view. **B** Exterior of skull base, inferior view.

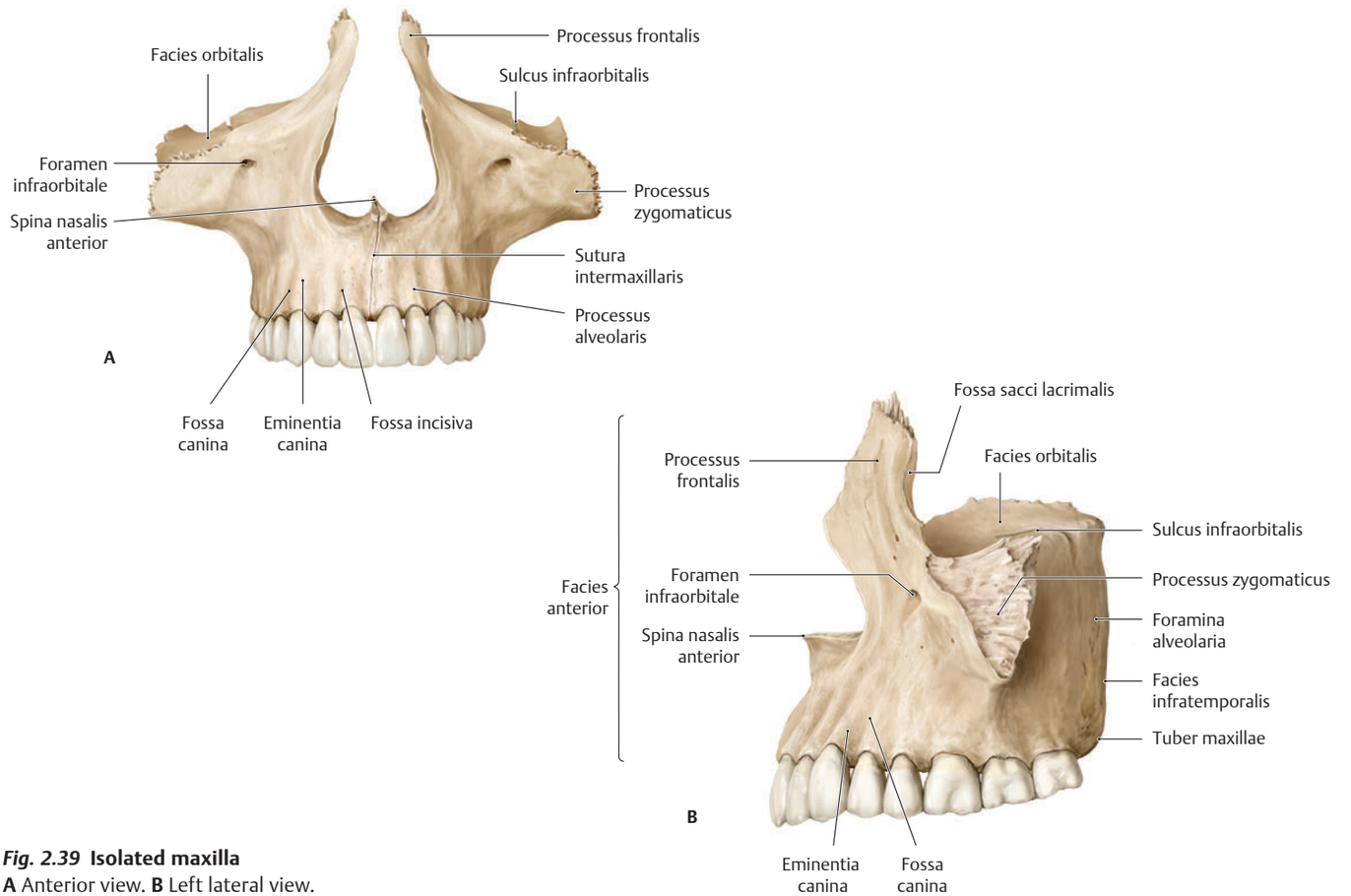


Fig. 2.39 **Isolated maxilla**
A Anterior view. **B** Left lateral view.

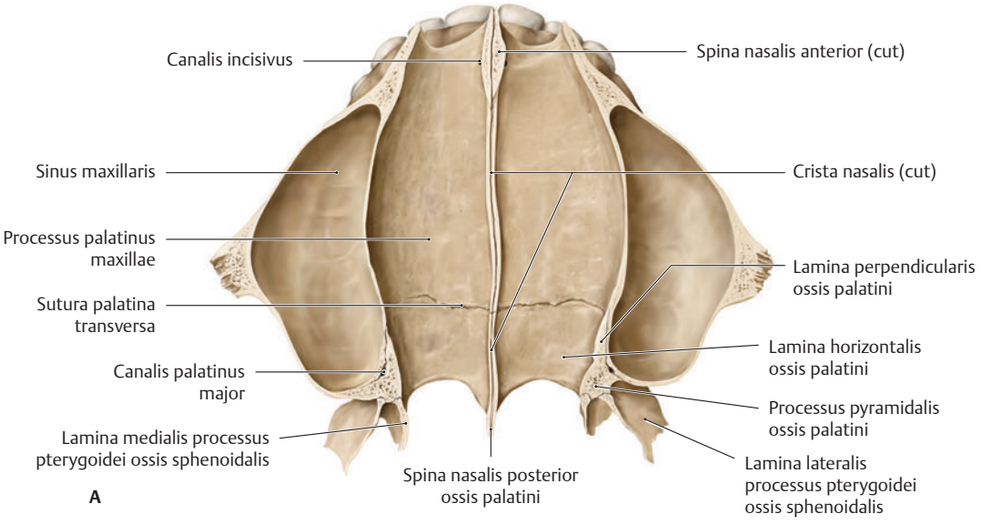
Fig. 2.40 **Bones of the palatum durum**

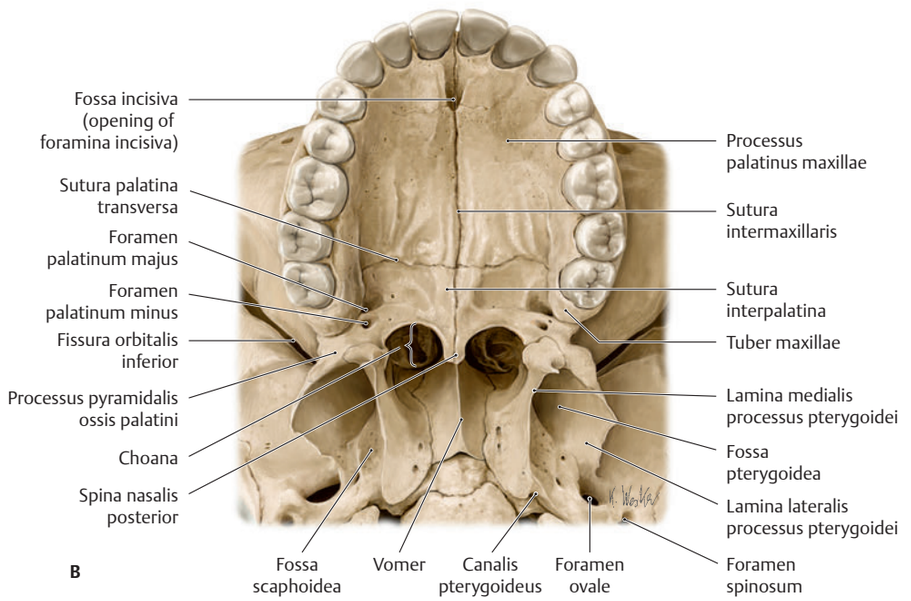
A Superior view. The upper part of the maxilla is removed. The floor of the cavitas nasi shown here and the roof of the cavitas oris (B) are formed by the union of the processus palatini of the two maxillae with the laminae horizontales of the two ossa palatina. Cleft palate results from a failed fusion of the processus palatini at the sutura palatina mediana (see p. 15).

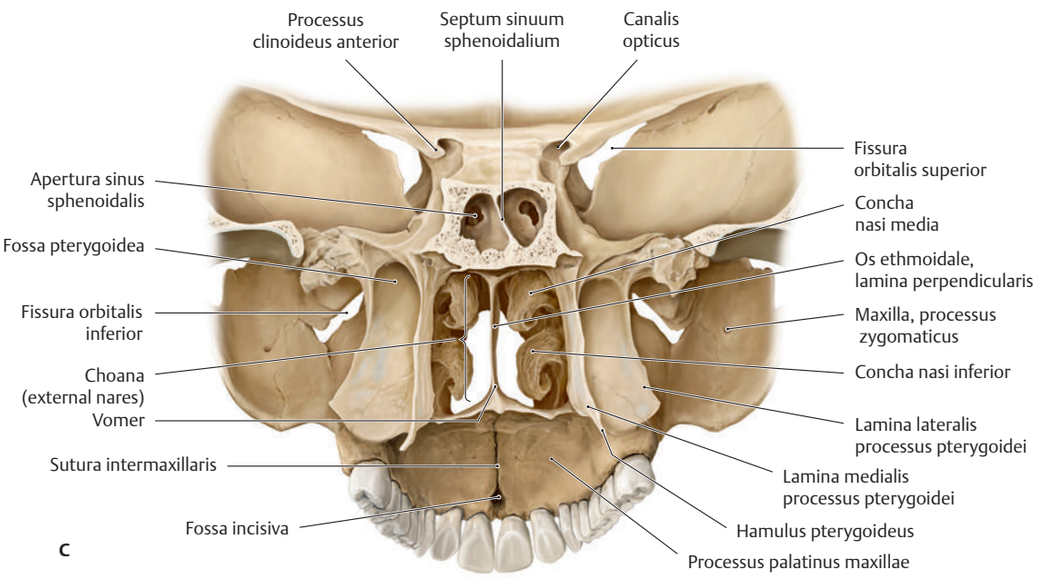
B Inferior view. The cavitas nasi communicates with the pars nasalis pharyngis via the choanae, which begin at the posterior border of the palatum durum. The two cavitates nasi communicate with the cavitas oris via the canales incisivi (A), which combine and emerge at the foramen incisivum.

C Oblique posterior view. This view illustrates the close anatomic relationship between the cavitates oris and nasi. Note: The processus pyramidalis of the os palatinum is integrated into the lamina lateralis processus pterygoidei of the os sphenoidale. The palatine margin of the vomer articulates with the palatum durum along the crista nasalis.

Tori are bony exostoses (lumps) that can be found on both jaws. Torus palatinus occurs in the center of the palatum durum; torus mandibularis occurs in the lingual premolar or molar region of the mandibula. Tori are completely benign but may cause problems for denture retention, in which case they can be surgically excised.







Mandibula & Os Hyoideum

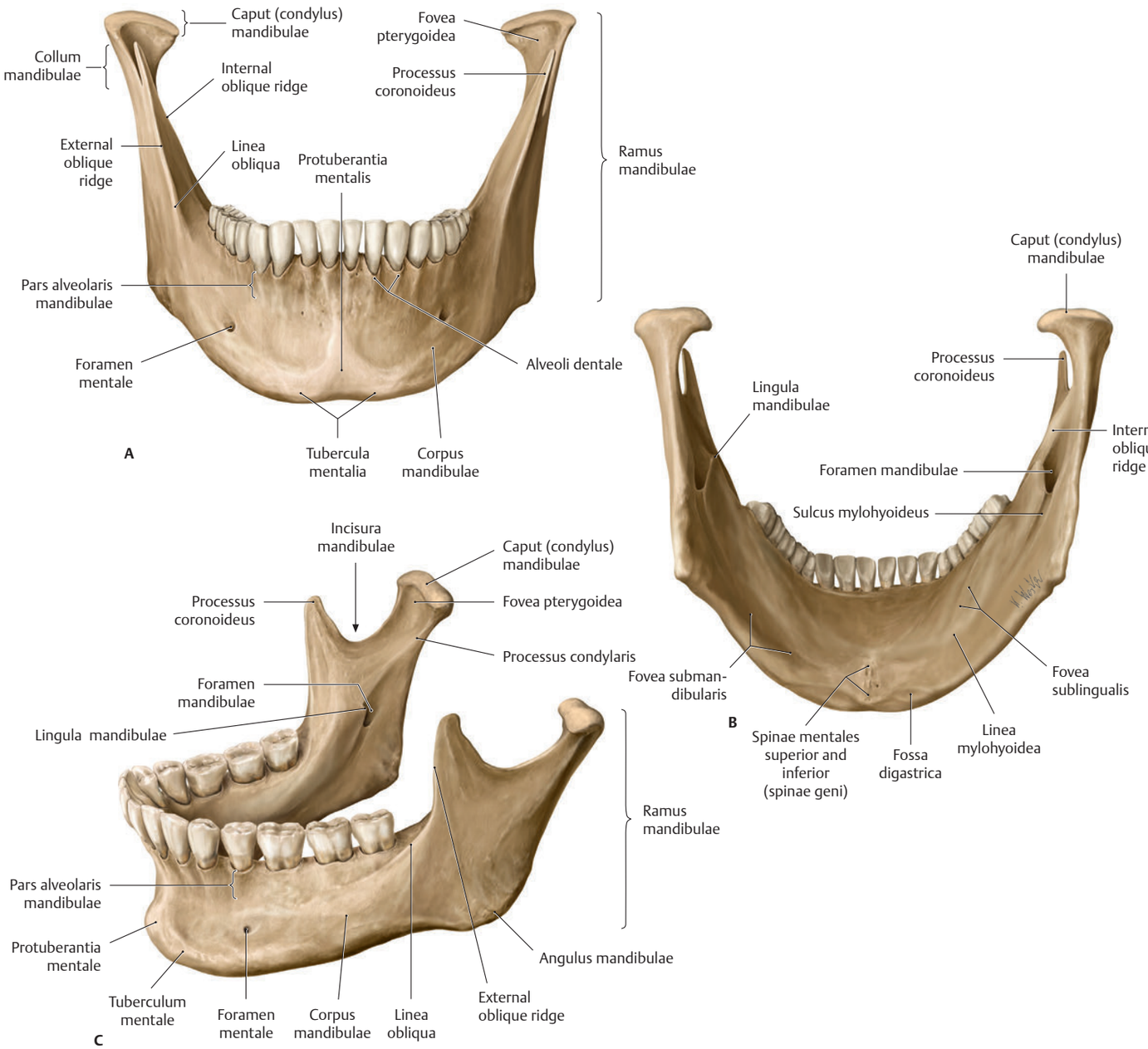


Fig. 2.41 **Mandibula**

A **Anterior view.** The mandibula is connected to the viscerocranium at the articulatio temporomandibularis, whose convex surface is the head of the condylus mandibularis. This "caput mandibulae" is situated atop the vertical (ascending) ramus mandibulae, which joins with the corpus mandibulae at the angulus mandibulae. The teeth are set in the alveoli dentum (pars alveolaris mandibulae) along the upper border of the corpus mandibulae. This part of the mandibula is subject to typical age-related changes as a result of dental development (see **Fig. 2.43**). The ramus mentalis of the nervus trigeminus exits through the foramen mentale. The location of this foramen is important in clinical examinations, as the tenderness of the nerve to pressure can be tested at that location.

B **Posterior view.** The foramen mandibulae is particularly well displayed in this view. It transmits the nervus alveolaris inferior, which supplies sensory innervation to the dentes mandibulares. Its terminal branch emerges from the foramen mentale. The foramen mandibulae and the foramen mentale are interconnected by the canalis mandibulae.

C **Oblique left lateral view.** This view displays the processus coronoideus, the processus condylaris, and the incisura mandibulae between them. The processus coronoideus is a site for muscular attachments, and the processus condylaris bears the caput mandibulae, which articulates with the discus articularis in the fossa mandibularis (glenoideus) of the os temporale. A depression on the medial side of the processus condylaris, the fovea pterygoidea, gives attachment to portions of the musculus pterygoideus lateralis.

D **Superior view.** This view displays the fossa retromolaris, trigonum retromolare, and buccal shelf. The fossa retromolaris is the insertion point for some fibers of the musculus temporalis. Lower dentures should be designed to avoid this area so that they are not dislodged during mastication. The buccal shelf (as a primary bearer of stress) and the trigonum retromolare are areas that are utilized to provide support for lower dentures.

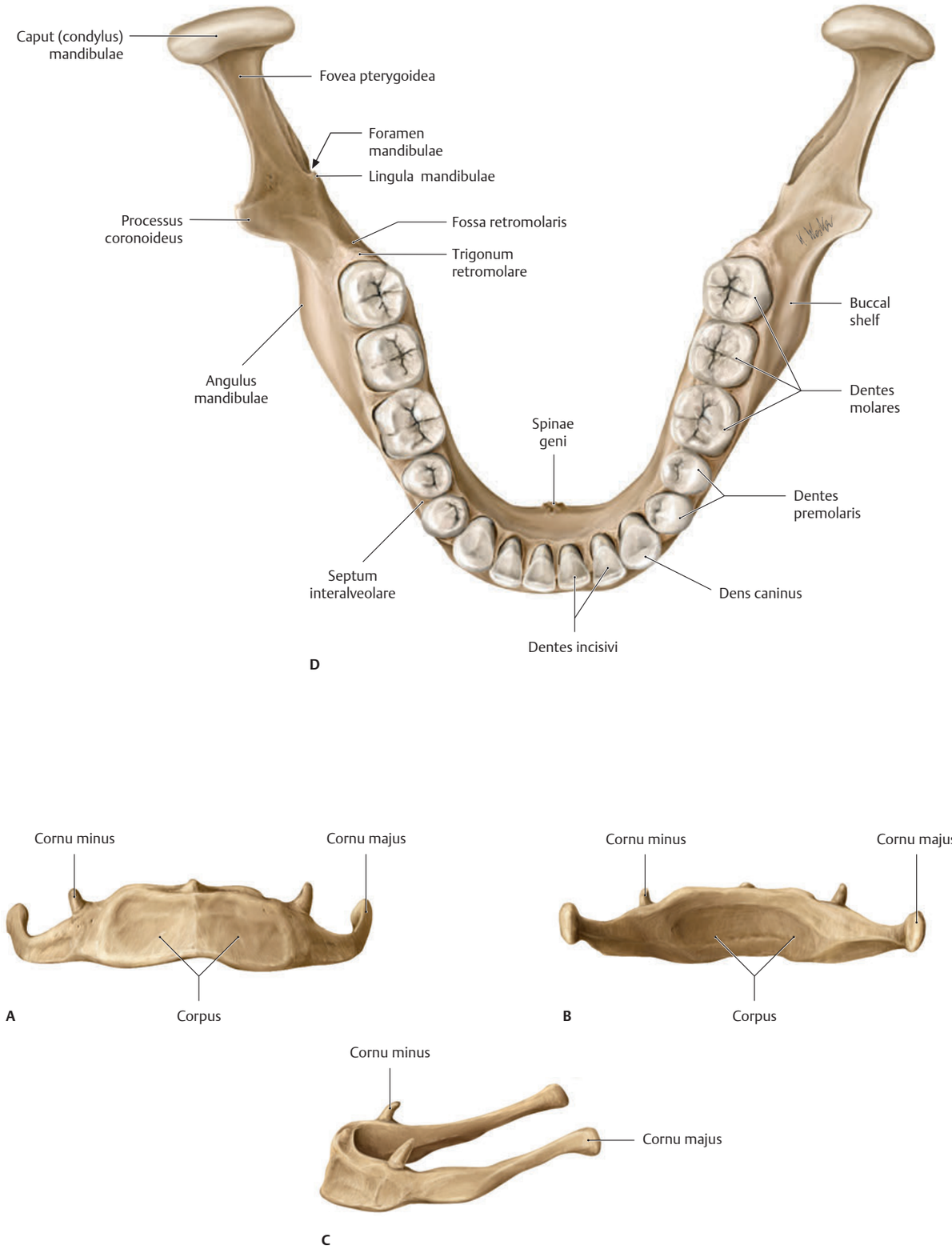


Fig. 2.42 **Os hyoideum**
A Anterior view. **B** Posterior view. **C** Oblique left lateral view. The os hyoideum is suspended by muscles and ligaments between the oral floor and the larynx. The cornu majus and corpus of the os hyoideum are palpable in the neck. The physiological movement of the os hyoideum can be palpated during swallowing.

Mandibula: Age-related Changes & Mandibular Fractures

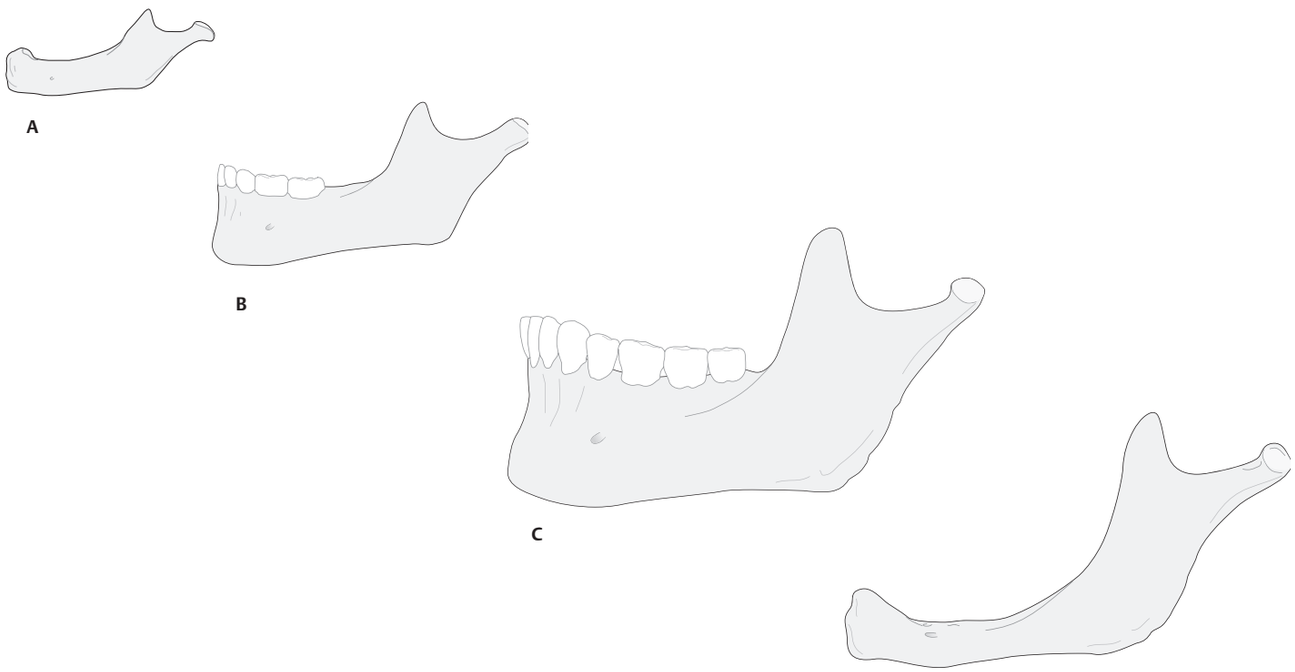


Fig. 2.43 **Age-related changes in the mandibula**
The structure of the mandibula is greatly influenced by the pars alveolaris and the dentes. Because the angulus mandibulae adapts to changes in the pars alveolaris, the angle between the corpus and ramus also varies with age-related changes in the dentition. The angle measures approximately 150 degrees at birth and approximately 120 to 130 degrees in adults, increasing to 140 degrees in the edentulous mandibula of old age.

A **At birth** the mandibula is without teeth, and the pars alveolaris has not yet formed.
B **In children** the mandibula bears the dentes decidui. The pars alveolaris is still relatively poorly developed because the dentes decidui are considerably smaller than the dentes permanentes.
C **In adults** the mandibula bears the dentes permanentes, and the pars alveolaris is fully developed.
D **In old age** with resorption of the pars alveolaris, the mandibula is edentulous (toothless).

Note: The resorption of the pars alveolaris with advancing age leads to a change in the position of the foramen mentale (which is normally located below the dens premolaris secundus, as in **C**). This change must be taken into account in surgery or dissections involving the nervus mentalis. The pars alveolaris is the portion of the maxilla and mandibula that supports the radices dentum. It is composed of two parts, the processus alveolaris and the supporting bone. The processus alveolaris lines the tooth sockets (alveoli). Supporting bone consists of cortical plates of compact bone on the inner and outer surfaces of the maxilla and mandibula and the intervening spongy bone between the cortical plates and processus alveolaris. The processus alveolaris is subject to resorption following tooth loss (a normal physiological process) and in certain disease states (e.g., abscess formation, cysts, osteoporosis). Basal bone is that portion of the maxilla and mandibula deep to the alveolar bone. It is not subject to resorption.

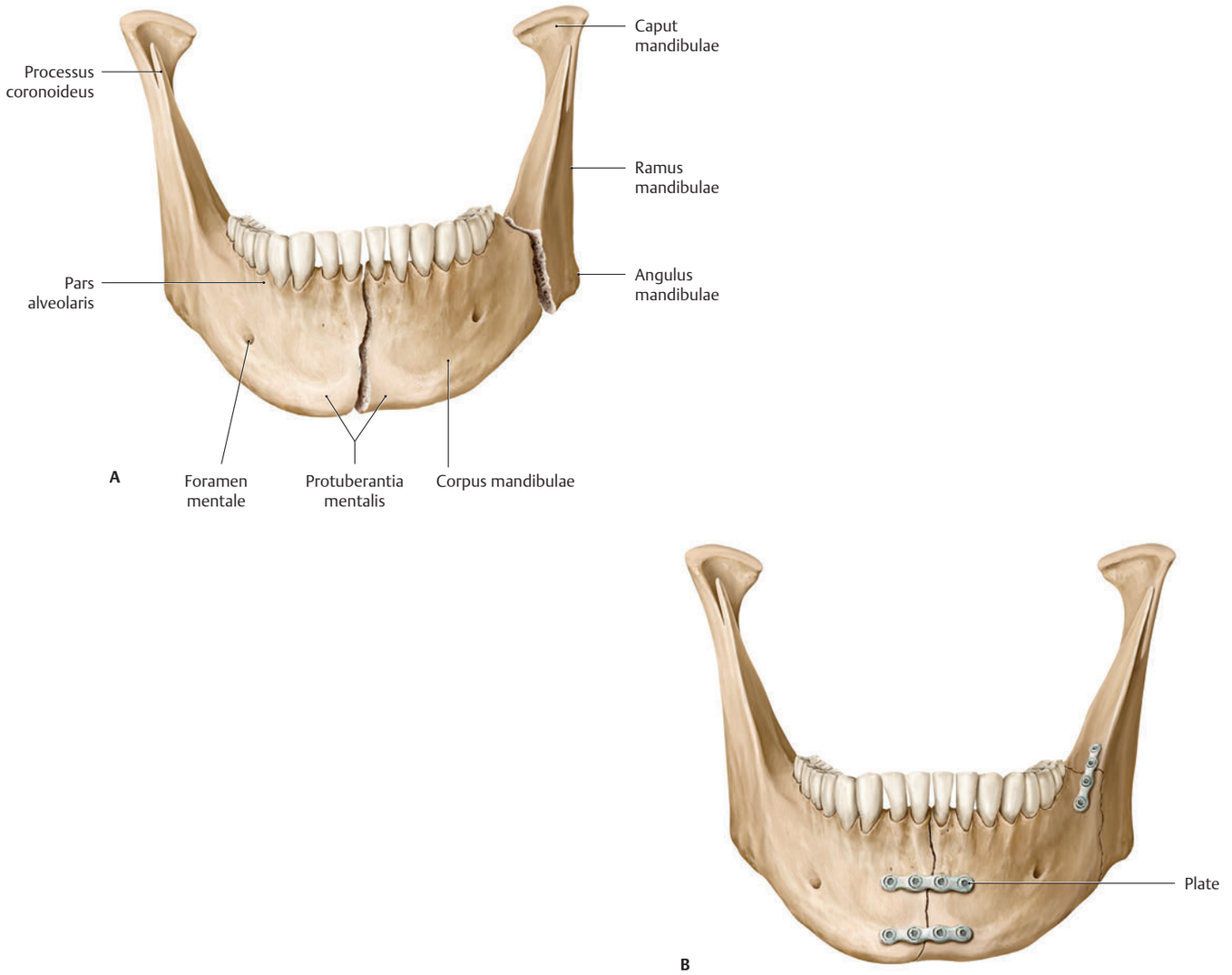


Fig. 2.44 **Mandibular fracture**
Anterior view. **A** Mandibular fracture. **B** Reduction and fixation of mandibular fracture. Mandibular fracture is a common injury, for example, following motor vehicle accidents, fights, or sporting accidents, due to the prominence of the mandibula and its relative lack of support. Most fractures occur in the corpus (~30%), condylus (~25%), angulus (~25%), and symphysis (~17%). To avoid misdiagnosis of the injury, the history should include not just information about the current injury but information about previous mandibular trauma or articulatio temporomandibularis (TMJ) dysfunction. Determine the patency of the airway and the presence of other injuries (facial lacerations, swellings, or hematomas). Inspect intraoral tissues for bruising, which, if present, is suggestive of a fracture of the corpus or symphysis. Palpate the mandibula from the symphysis to the angulus, noting any swelling, tenderness, or step deformities. Next palpate the condylus through the meatus acusticus externus; tenderness may indicate a fracture at this site. Note any deviation on opening the mouth. With condylar fractures, the mandibula deviates toward the side of the fracture. Note also any obstruction to mouth opening, e.g., trismus (lock jaw due to spasm of the muscles of mastication) or impaction of the processus coronoideus. Now evaluate the occlusion. If the teeth do not occlude as normal, this is highly suggestive of mandibular fracture, although this can also occur following tooth subluxation (loosening) or TMJ injury. Note any areas of altered sensation (paresthesia, dysesthesia, or anesthesia). The latter is suggestive of a fracture distal to the foramen mandibulae. Following this, the mandibula should be grasped at either side of the suspected fracture and gently manipulated to assess mobility. Confirm the diagnosis via either radiography or CT scans. Treat with antibiotics to prevent infection, followed by reduction (to the patient's normal occlusion) and surgical fixation of the fracture. The fixation method depends on many factors including the type and site of fracture and may involve the use of bars, wires, or plates.
The double mandibular fracture shown here is treated in a two-step process. First, the fracture at the midline is fixated with metal plates followed by the angulus fracture. Note that two plates provide much more stability than a single plate.

Neurovascular Pathways through the Skull Base

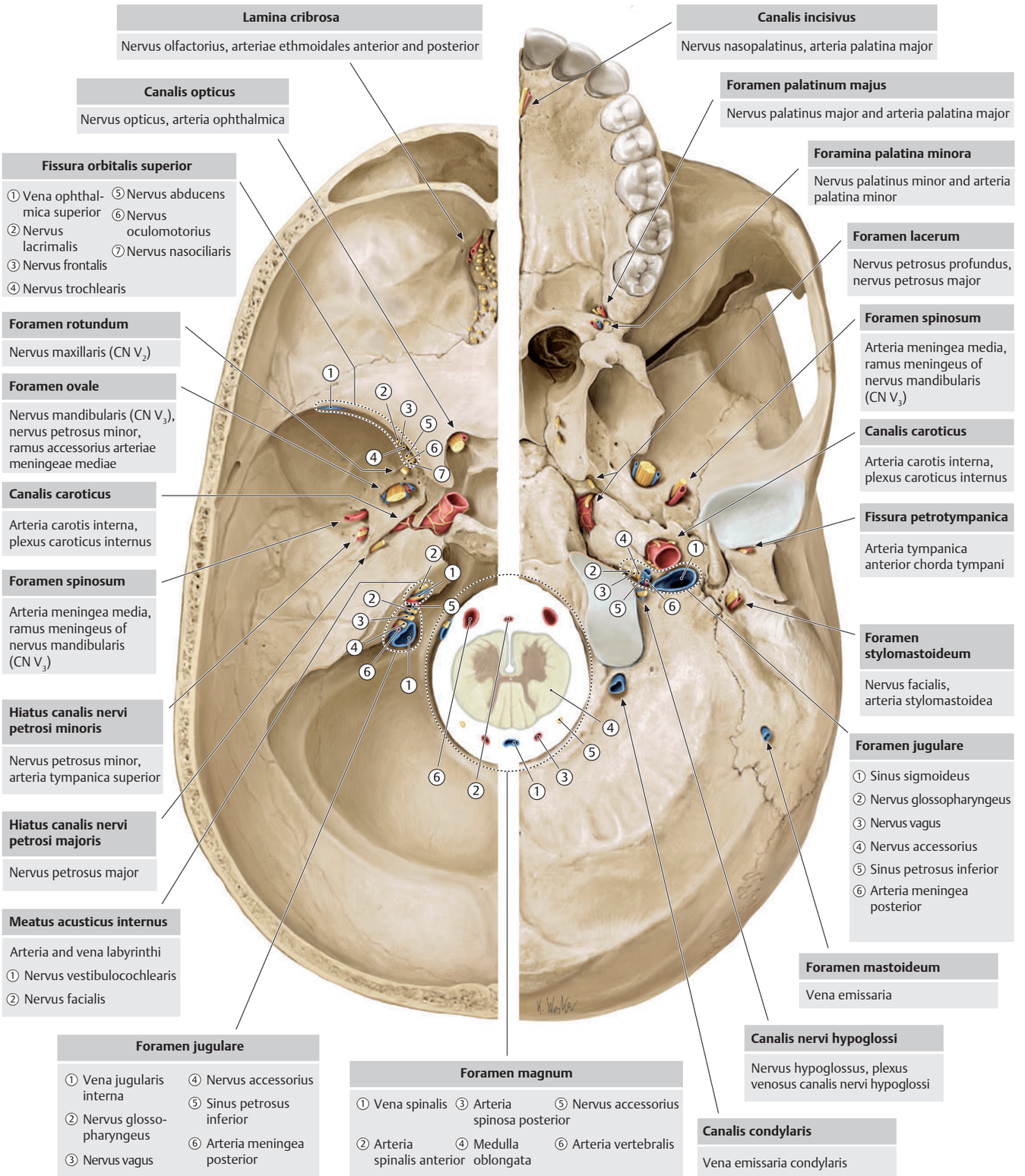


Fig. 2.45 **Passage of neurovascular structures through the skull base**
A Cavitas cranii (interior of skull base), superior view.
B Exterior of skull base, inferior view.
This image and the corresponding table only address structures entering and exiting the skull. Many neurovascular structures pass through bony canals within the skull (to fossa pterygopalatina, fossa infratemporalis, etc.).
Note: The nervus petrosus profundus and nervus petrosus major travel over the surface of foramen lacerum but not through it.

Table 2.3 **Openings in the skull base**

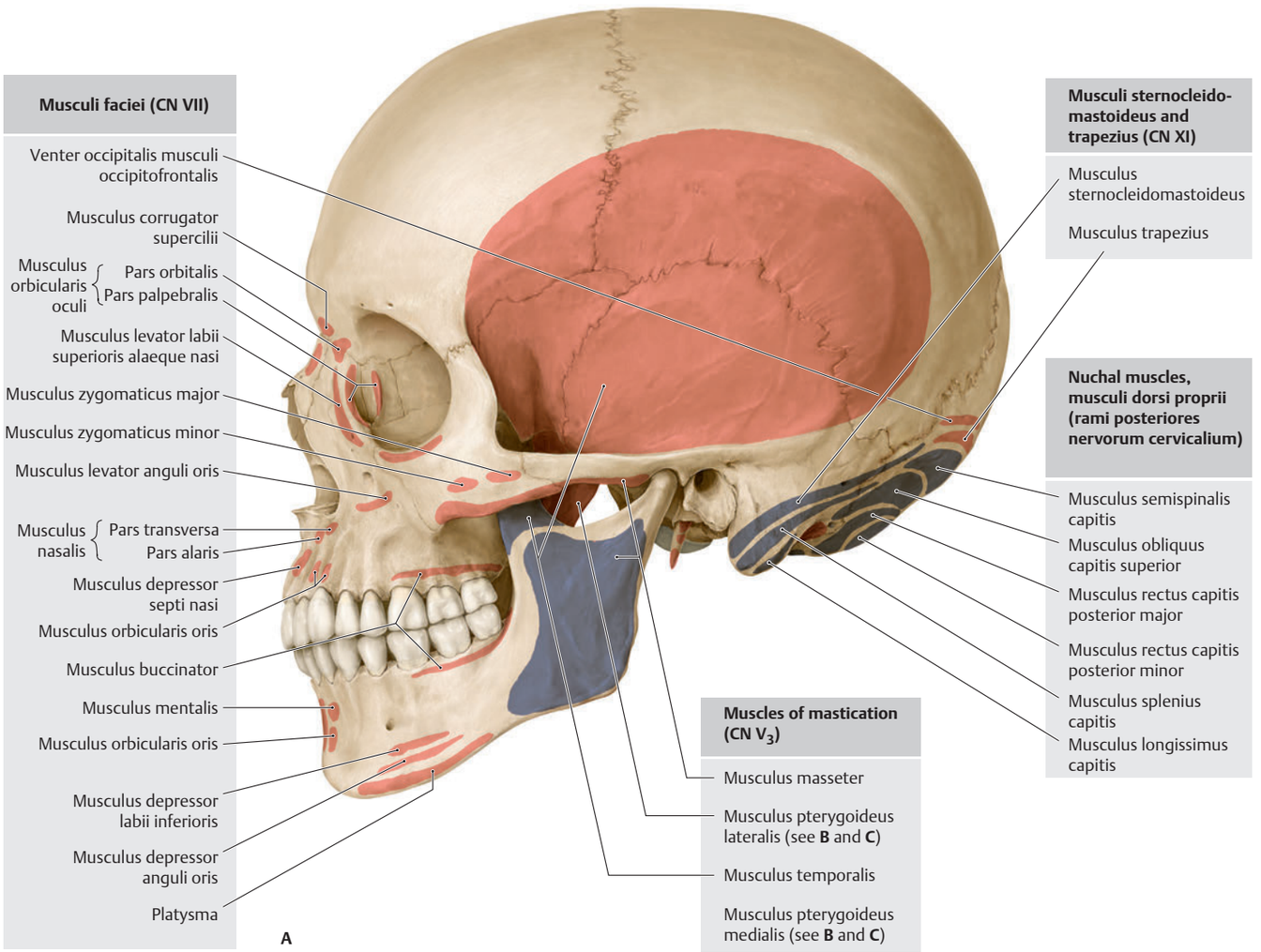
Cranial cavity	Opening	Transmitted structures	
		Nerves	**Arteries and veins**
Internal view, base of the skull			
Fossa cranii anterior	Lamina cribrosa	• CN I (fila olfactoria collected to form nervus olfactorius)	• Arteriae ethmoidales anterior and posterior (from arteria ophthalmica) • Venae ethmoidales (to vena ophthalmica superior)
Fossa cranii media	Canalis opticus	• CN II (nervus opticus)	• Arteria ophthalmica (from arteria carotis interna)
	Fissura orbitalis superior	• CN III (nervus oculomotorius) • CN IV (nervus trochlearis) • CN VI (nervus abducens) • CN V_1 (nervus ophthalmica) divisions (nervi lacrimalis, frontalis, and nasociliaris)	• Venae opthalmicae superior and inferior (to sinus cavernosus) (*Note:* The vena ophthalmica inferior also drains through the fissura orbitalis inferior to the plexus pterygoideus.)
	Foramen rotundum*	• CN V_2 (nervus maxillaris)	
	Foramen ovale	• CN V_3 (nervus mandibularis) • Nervus petrosus minor (CN IX)	• Ramus accessorius arteriae meningeae mediae (from mandibular part of arteria maxillaris)
	Foramen spinosum	• CN V_3, ramus meningeus	• Arteria meningea media (from mandibular part of arteria maxillaris)
	Canalis caroticus	• Plexus caroticus internus (postganglionic sympathetics from ganglion cervicale superius)	• Arteria carotis interna
	Hiatus canalis nervi petrosi majoris	• Nervus petrosus major (CN VII)	• Ramus petrosus (from arteria meningea media)
	Hiatus canalis nervi petrosi minoris	• Nervus petrosus minor (CN IX)	• Ramus tympanica superior (from arteria meningea media)
Fossa cranii posterior	Meatus acusticus internus	• CN VII (nervus facialis) • CN VIII (nervus vestibulocochlearis)	• Arteria labyrinthi (from arteria basilaris) • Venae labyrinthi (to sinus petrosus inferior or sinus transversus)
	Foramen jugulare	• CN IX (nervus glossopharyngeus) • CN X (nervus vagus) • CN XI (nervus accessorius, radix cranialis)	• Vena jugularis interna (bulbus superior) • Sinus sigmoideus (to bulbus superior venae jugularis) • Arteria meningea posterior (from arteria pharyngea ascendens) • Sinus petrosus inferior
	Canalis nervi hypoglossi	• CN XII (nervus hypoglossus)	• Plexus venosus canalis nervi hypoglossi
	Foramen magnum	• Medulla oblongata with meningeal coverings • CN XI (nervus accessorius)	• Arteriae vertebrales • Arteriae spinales anterior and posterior (from arteria vertebralis) • Venae emissariae
External aspect, base of the skull (where different from internal aspect)			
	Canalis incisivus	• Nervus nasopalatinus (from CN V_2)	• Branch of arteria palatina major
	Foramen palatinum majus	• Nervus palatinus major (from CN V_2)	• Arteria palatina major (from pterygopalatine part of arteria maxillaris or arteria palatina descendens)
	Foramen palatinum minus	• Nervus palatinus minor (from CN V_2)	• Arteriae palatinae minores (from pterygopalatine part of arteria maxillaris or as branch of arteria palatina major or arteria palatina descendens)
	Foramen lacerum**	• Nervus petrosus profundus (from ganglion cervicale superius via plexus caroticus internus) • Nervus petrosus major (from CN VII)	
	Fissura petrotympanica	• Chorda tympani (from CN VII)	• Arteria tympanica anterior (from mandibular part of arteria maxillaris)
	Foramen stylomastoideum	• Nervus facialis (CN VII)	• Arteria stylomastoidea (from arteria auricularis posterior)
	(Posterior) canalis condylaris		• Vena emissaria condylaris (to sinus sigmoideus)
	Foramen mastoideum		• Vena emissaria mastoidea (to sinus sigmoideus)

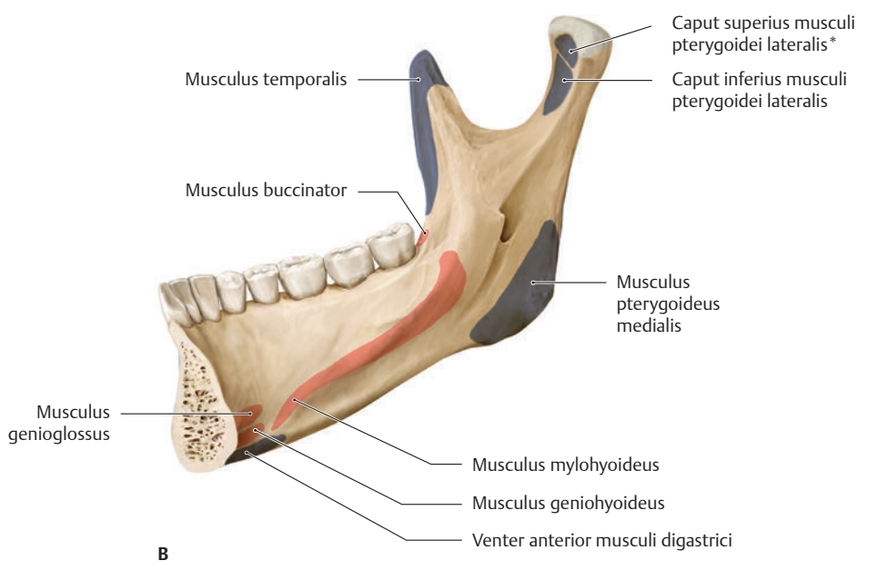
*The external opening of the foramen rotundum is located in the fossa pterygopalatina, which is located deep on the lateral surface of the base of the skull and is not visible here.

**Structures travel over the superior surface of the foramen lacerum, not through it, from external to internal (with the exception of lymphatic vessels and venae emissariae).

Muscles of the Head: Origins & Insertions

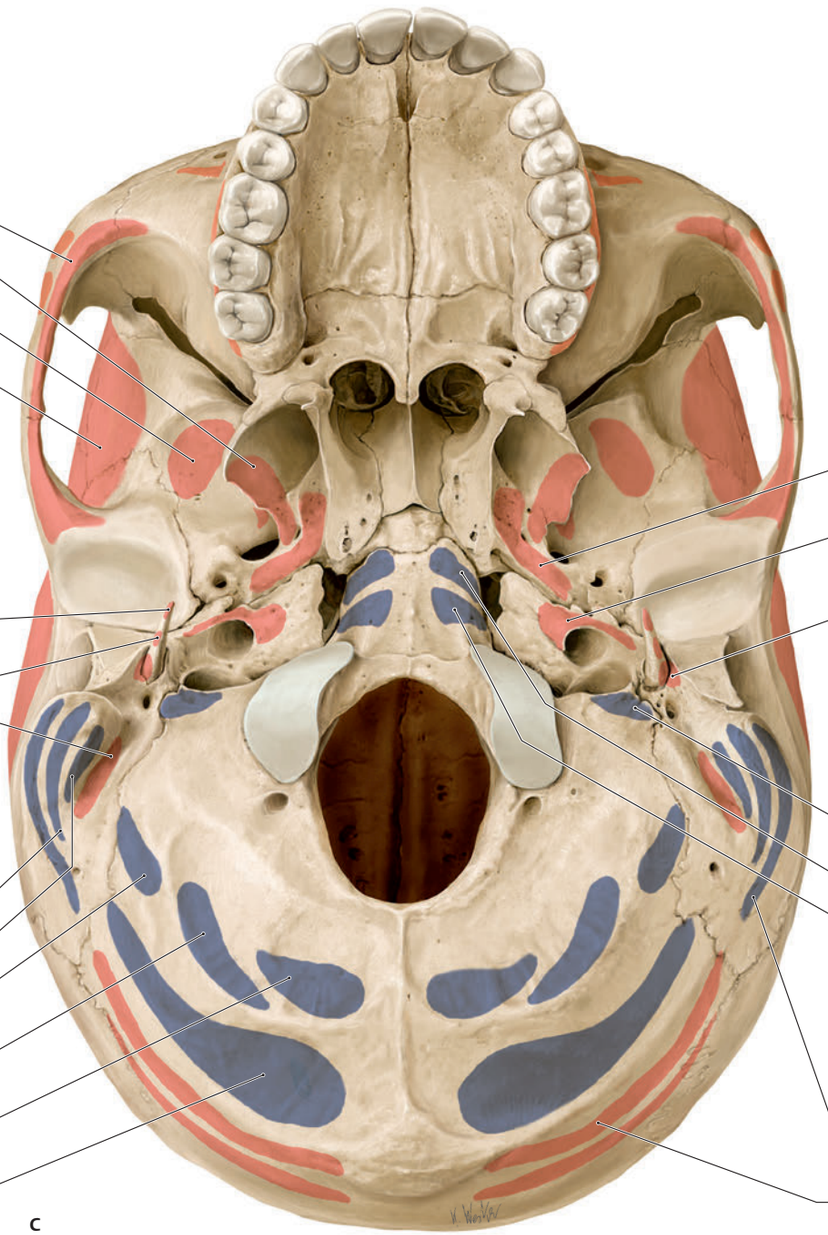
The bony origins and insertions of the muscles are indicated by color shading: origins (red) and insertions (blue).





*Primarily inserts into discus articularis

Fig. 2.46 **Origins and insertions on the skull**
A Left lateral view.
B Inner surface of right hemimandible.
C Inferior view of skull base.
Note: The musculi stylohyoideus, styloglossus, and stylopharyngeus originate on the processus styloideus.



Muscles of mastication (CN V_3)

- Musculus masseter
- Musculus pterygoideus medialis
- Musculus pterygoideus lateralis
- Musculus temporalis

- Musculus tensor veli palatini (CN V_3)
- Musculus levator veli palatini (plexus pharyngeus)
- Musculus stylopharyngeus (CN IX)

- Musculus styloglossus (CN XII)
- Musculus stylohyoideus
- Venter posterior musculi digastrici (CN VII)

Prevertebral muscles (rami anteriores nervorum cervicalium and plexus cervicalis)

- Musculus rectus capitis lateralis
- Musculus longus capitis
- Musculus rectus capitis anterior

Nuchal muscles, musculi dorsi proprii (rami posteriores nervorum cervicalium)

- Musculus splenius capitis
- Musculus longissimus capitis
- Musculus obliquus capitis superior
- Musculus rectus capitis posterior major
- Musculus rectus capitis posterior minor
- Musculus semispinalis capitis

Musculi sternocleido-mastoideus and trapezius (CN XI)

- Musculi sternocleido-mastoideus
- Musculus trapezius

C

Arteries of the Head & Neck: Overview & Arteria Subclavia

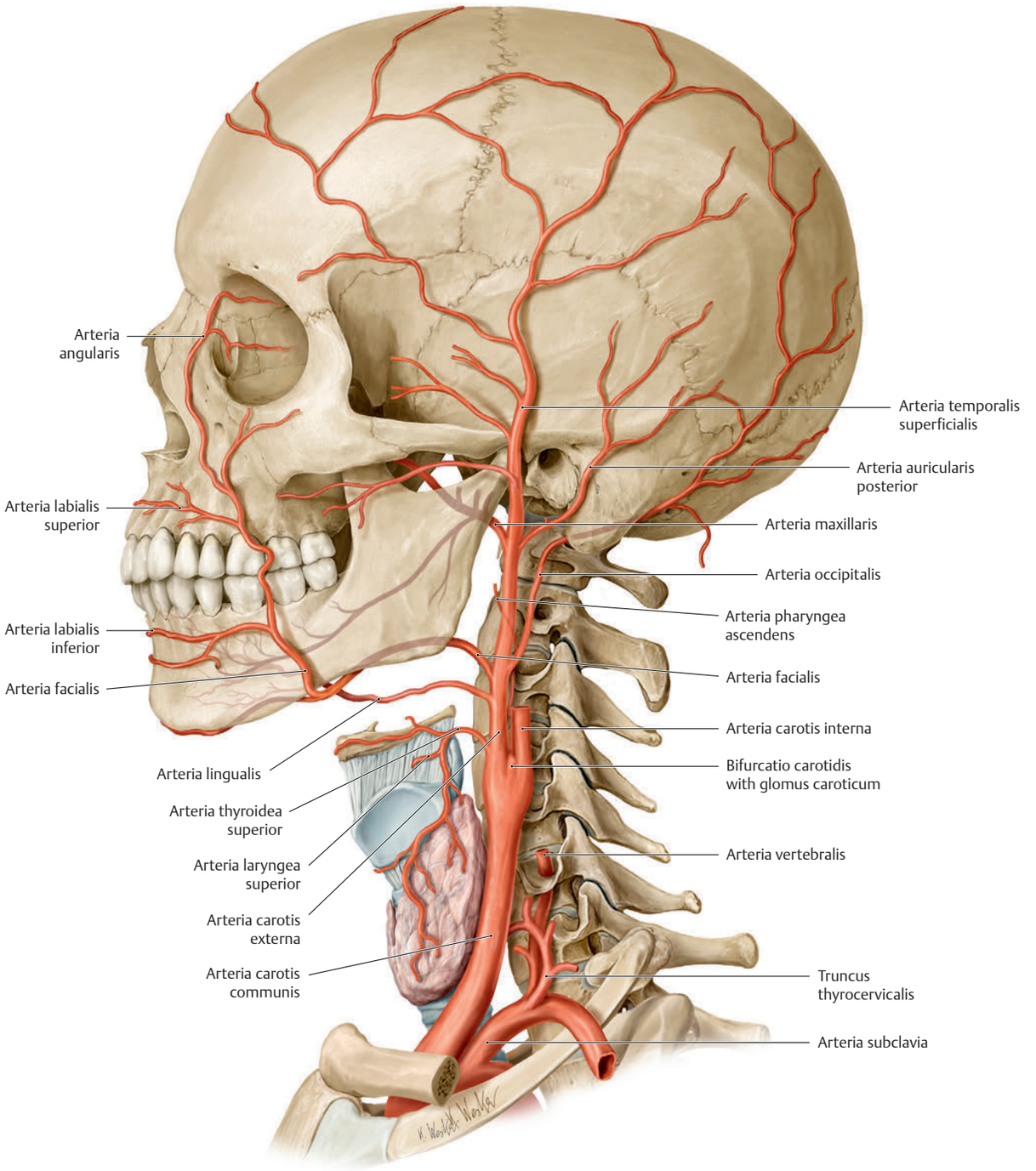


Fig. 3.1 **Overview of the arteries of the head and neck**
Left lateral view. The left arteria carotis communis arises from the arcus aortae; the right arteria carotis communis from the truncus brachiocephalicus. Each arteria carotis communis divides into an arteria carotis interna and an arteria carotis externa at the bifurcatio carotidis, which is at the approximate level of the fourth cervical vertebra. The glomus caroticum is located at the bifurcatio carotidis. It contains the chemoreceptors that respond to oxygen deficiency in the blood (hypoxia) and to changes in pH (both are important in the regulation of breathing). The arteria carotis interna does not branch further before entering the skull, where it mainly supplies blood to the brain. It also gives off branches that supply areas of the facial skeleton that emerge from the cranium.

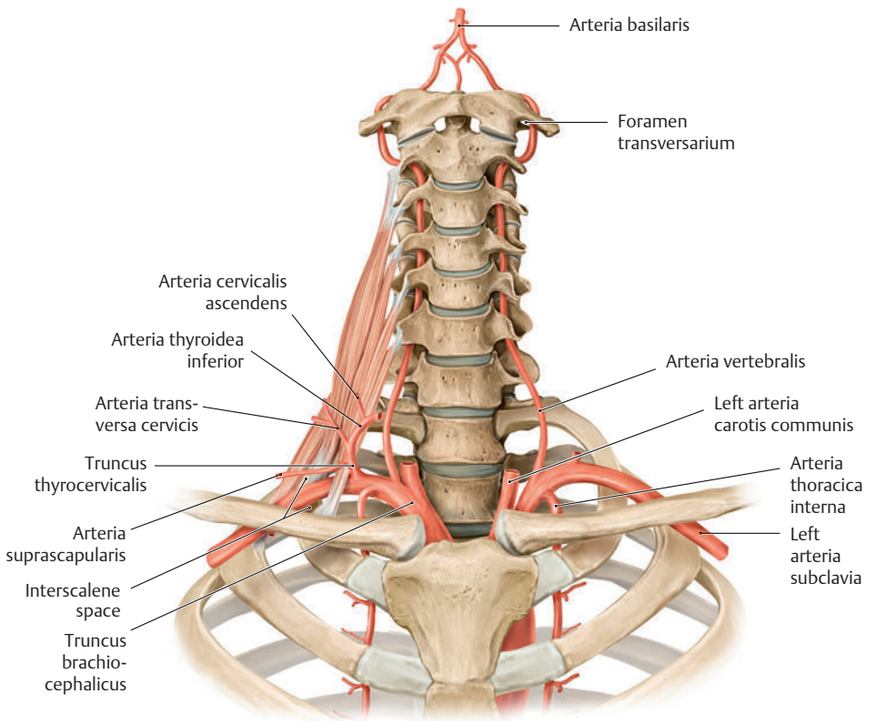


Fig. 3.2 **Arteria subclavia and its branches**
Anterior view. The arteria subclavia distributes a number of branches to structures located at the base of the neck and in the region of the apertura thoracis superior. Note that the branches of the arteria subclavia may arise in a variable sequence. After emerging from the apertura thoracis superior, the arteria subclavia passes through the interscalene space (between the musculus scalenus anterior and musculus scalenus medius) and on into the axilla as the arteria axillaris. Each *arteria vertebralis* arises from the posterior aspect of the arteria subclavia on each side and ascends through the foramina in the processus transversi of the vertebrae cervicales (C6–C1). After entering the skull through the foramen magnum, the arteriae vertebrales unite to form the arteria basilaris and contribute to the formation of both the arteriae cerebri, forming anastomoses (circulus arteriosus cerebri) that have major clinical importance in supplying the blood to the brain.

Table 3.1 **Branches of the arteria subclavia**

Artery	Branch	Further branches	Regions supplied
Arteria subclavia	Arteria thoracica interna		Internal anterior chest wall
	Arteria vertebralis	Rami meningei	Falx cerebelli
		Arteria spinalis posterior	Posterior medulla spinalis, especially the columna posterior; medulla oblongata (nucleus cuneatus and nucleus gracilis)
		Arteria spinalis anterior	Meninges; anterior medulla spinalis; medulla oblongata (nucleus posterior nervi vagi, nucleus ambiguus, nucleus nervi accessorii and nucleus nervi hypoglossi)
		Arteria inferior posterior cerebelli	Cerebellum, medulla oblongata (nuclei cochleares, nuclei vestibulares, nervus posterior nervi vagi, nucleus ambiguus)
	Truncus thyrocervicalis	Arteria thyroidea inferior	Inferior portion of glandula thyroidea and larynx, upper trachea, upper oesophagus, deep neck muscles
		Arteria suprascapularis	Musculi supraspinatus and infraspinatus, shoulder joint
		Arteria transversa cervicis	Musculus trapezius and surrounding tissues
	Truncus costocervicalis	Arteria cervicalis profunda	Muscles at the root of the neck
		Arteria intercostalis suprema	Posterior part of the 1st and 2nd spatia intercostalia
	Arteria dorsalis scapulae*		Musculi levator scapulae, rhomboideus and trapezius

* Arises from the arteria subclavia in around two thirds of individuals and from the arteria transversa cervicis in the remaining one third.

Arteriae Carotides Externa & Interna: Overview

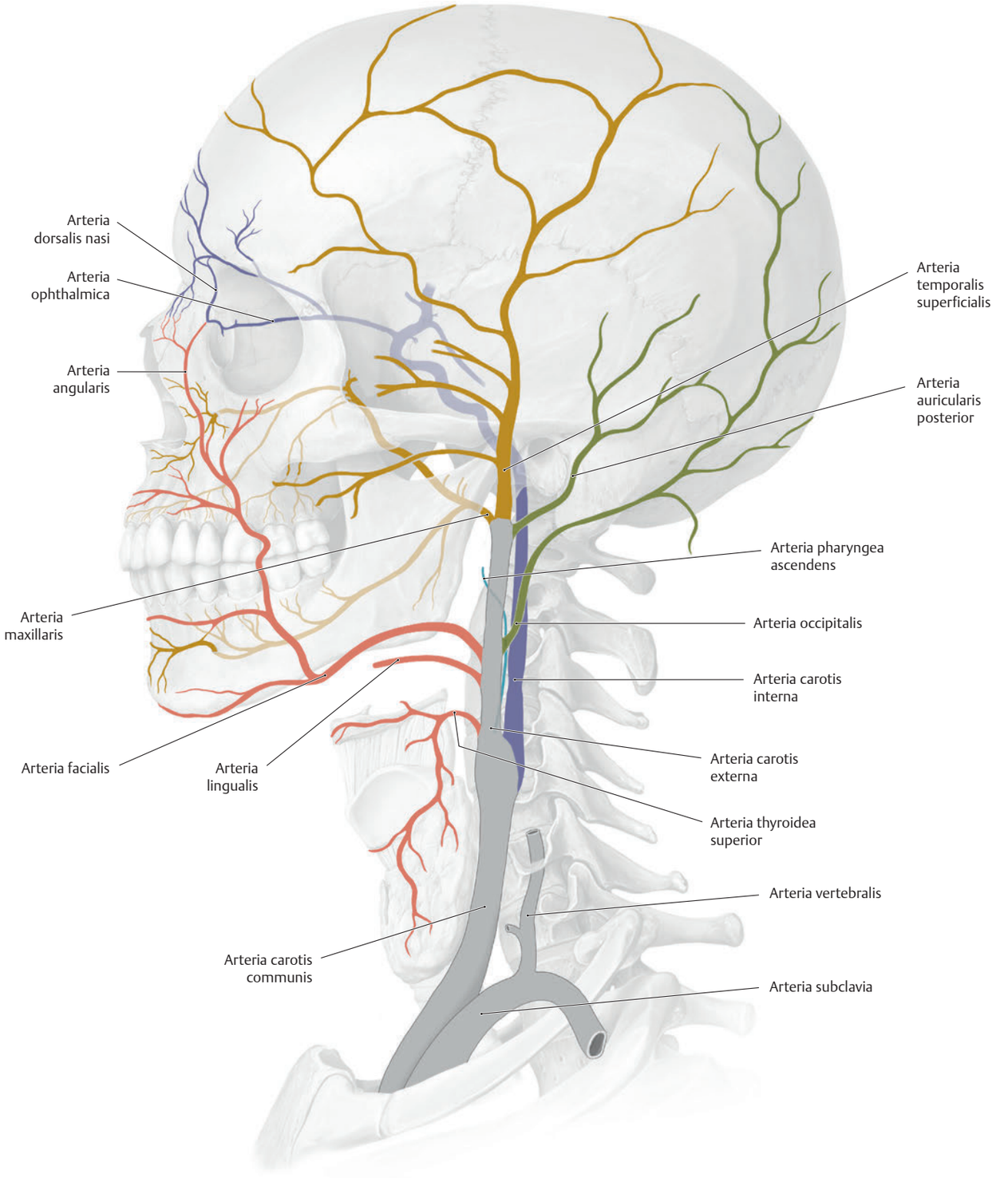


Fig. 3.3 **Arteries of the head**
Left lateral view. The arteria carotis communis divides into the arteria carotis interna (purple) and the arteria carotis externa (gray) at the bifurcatio carotidis (at the level of the C4 vertebra, between the cartilago thyroidea and os hyoideum). The arteria carotis externa divides into eight major branches that supply the scalp, face, and structures of the head and neck. These eight branches can be arranged into four groups: anterior (red), medial (blue), posterior (green), and terminal (yellow). The arteria carotis interna does not branch before entering the skull. It gives off branches within the cavitas cranii.

The arteria ophthalmica branch of the arteria carotis interna provides branches that will anastomose with branches of the arteria facialis on the face (see **Fig. 3.12**).

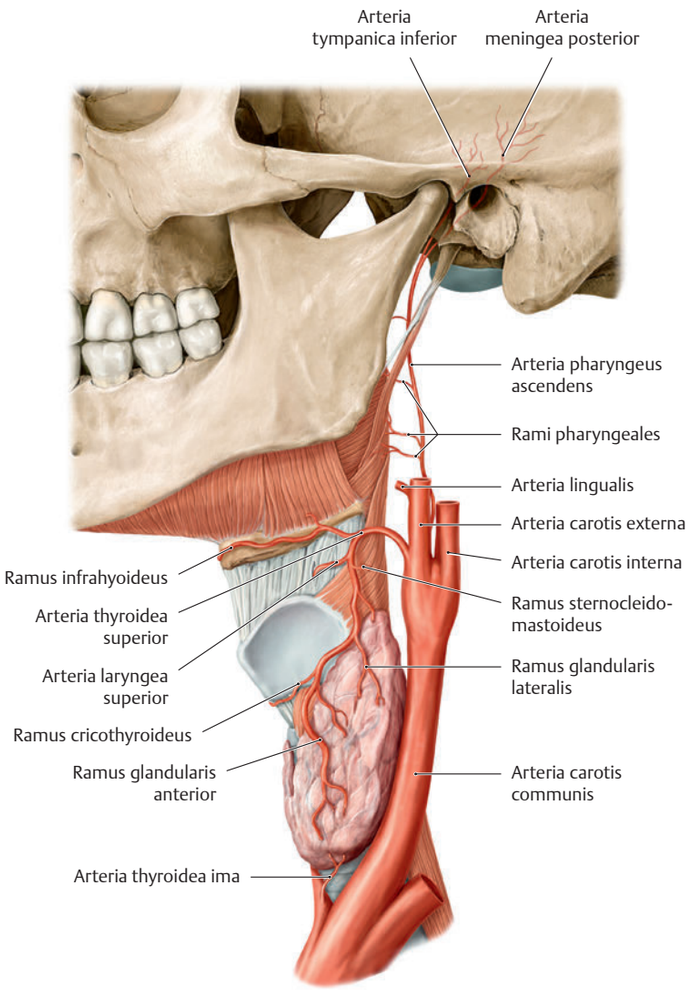
A carotid bruit is a noise ("swooshing" sound) caused by turbulent blood flow in the arteria carotis. It is suggestive of arteria carotis stenosis (narrowing) due to atherosclerosis (hardening of the arteries). It is best heard with the stethoscope placed over the bifurcatio carotidis (at the upper border of the cartilago thyroidea). Surgical intervention is necessary for those with >60% lumen stenosis, which is indicated by imaging.

Table 3.2 **Branches of the arteriae carotides externa and interna**

Artery	Branch	Regions supplied
Arteria carotis externa* (gray)	Arteria thyroidea superior (red)	Larynx, glandula thyroidea, pharynx, musculus sternocleidomastoideus
	Arteria pharyngea ascendens (blue)	Muscles of the pharyngeal wall, mucosa of the auris media, dura, fossa cranii posterior
	Arteria lingualis (red)	Floor of the cavitas oris, lingua, glandula sublingualis, epiglottis, musculi suprahyoidei
	Arteria facialis (red)	Superficial face, glandula submandibularis, pharyngeal wall, palatum molle, tonsillae palatinae, venter anterior musculi digastrici, musculus mylohyoideus, nose and septum nasi
	Arteria occipitalis (green)	Scalp in occipital region; posterior neck muscles
	Arteria auricularis posterior (green)	Cavitas tympanica, posterior auricula, glandula parotida, posterior scalp
	Arteria maxillaris (yellow)	Mandibular and maxillary dentition, muscles of mastication, posteromedial facial skeleton, cavitas nasi, face, and meninges
	Arteria temporalis superficialis (yellow)	Scalp of forehead and vertex, soft tissue below arcus zygomaticus, musculus masseter, glandula parotidea, external orbital wall, musculus orbicularis oculi
Arteria carotis interna (purple)	Arteriae caroticotympanicae	Tuba auditiva and anterior wall of cavitas tympani
	Arteriae caroticotympanicae	Anastomosis with arteria carotis externa
	Arteriae hypophysiales superior and inferior	Hypophysis
	Ramus sinus cavernosi	Anastomosis with arteria carotis externa
	Ramus meningeus	Meninges of the fossa cranii anterior
	Rami ganglionares trigeminales	Ganglion trigeminale
	Arteria ophthalmica	Nervus opticus, chiasma opticum, tractus opticus, retina, extraocular muscles, palpebrae, glandula lacrimalis, forehead, cellulae ethmoidales, sinus frontalis, lateral nasal wall, dorsum nasi, and meninges
	Arteria cerebri anterior	Medial aspect of lobi frontalis and parietalis, corpus callosum
	Arteria cerebri media	Lobi frontalis, parietalis, and temporalis
	Arteria communicans posterior	Anastomosis with arteria cerebri as part of circulus arteriosus cerebri
	Arteria communicans posterior	Plexus choroideus of the ventriculi lateralis and tertius, chiasma opticum and tractus opticus, capsula interna, corpus geniculatum laterale, globus pallidus, nucleus caudatus, hippocampus, amygdala, substantia nigra, nucleus ruber, crus cerebelli

* Anterior branches of arteria carotis externa are red; medial branches are blue; posterior branches are green; and terminal branches are yellow
** There is also an arteria canalis pterygoidei from the 3rd part of the arteria maxillaris.

Arteria Carotis Externa: Anterior & Medial Branches



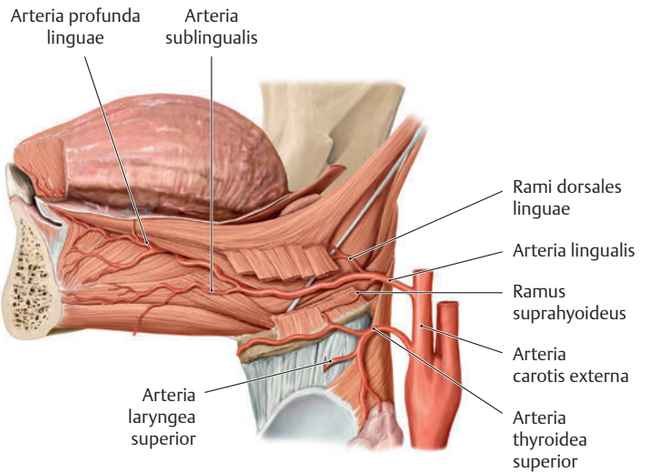


Fig. 3.5 **Arteria lingualis and its branches**
Left lateral view. The arteria lingualis is the second anterior branch of the arteria carotis externa. It has a relatively large caliber, providing the tongue and cavitas oris with its rich blood supply. It also gives off branches to the tonsillae palatinae.

Fig. 3.4 **Arteriae thyroidea superior and pharyngea ascendens**
Left lateral view. The arteria thyroidea superior is typically the first branch to arise from the arteria carotis externa. One of the anterior branches, it supplies the larynx (via the arteria laryngea superior) and glandula thyroidea. The arteria pharyngea ascendens springs from the medial side of the arteria carotis externa, usually arising above the level of the arteria thyroidea superior.

Table 3.3 **Branches of the arteriae thyroidea superior, lingualis, and pharyngea ascendens**

Branch of arteria carotis externa	Further branches	Region supplied
Arteria thyroidea superior	Arteria laryngea superior	Larynx
	Rami glandulares	Glandula thyroidea
	Ramus sternocleidomastoideus	Musculus sternocleidomastoideus
	Muscular branches	Pharynx
	Ramus infrahyoideus	Region of membrana thyrohyoidea
	Ramus cricothyroideus	Region of the ligamentum cricothyroideum
Arteria lingualis	Ramus suprahyoideus	Musculi suprahyoidei
	Rami dorsales linguae	Base of lingua, epiglottis
	Arteria sublingualis	Glandula sublingualis, lingua, floor of the cavitas oris
	Arteria profunda linguae	Lingua
Arteria pharyngea ascendens	Rami pharyngeales	Muscles of the pharyngeal wall
	Arteria tympanica inferior	Mucosa of auris media
	Arteria meningea posterior	Dura; fossa cranii posterior

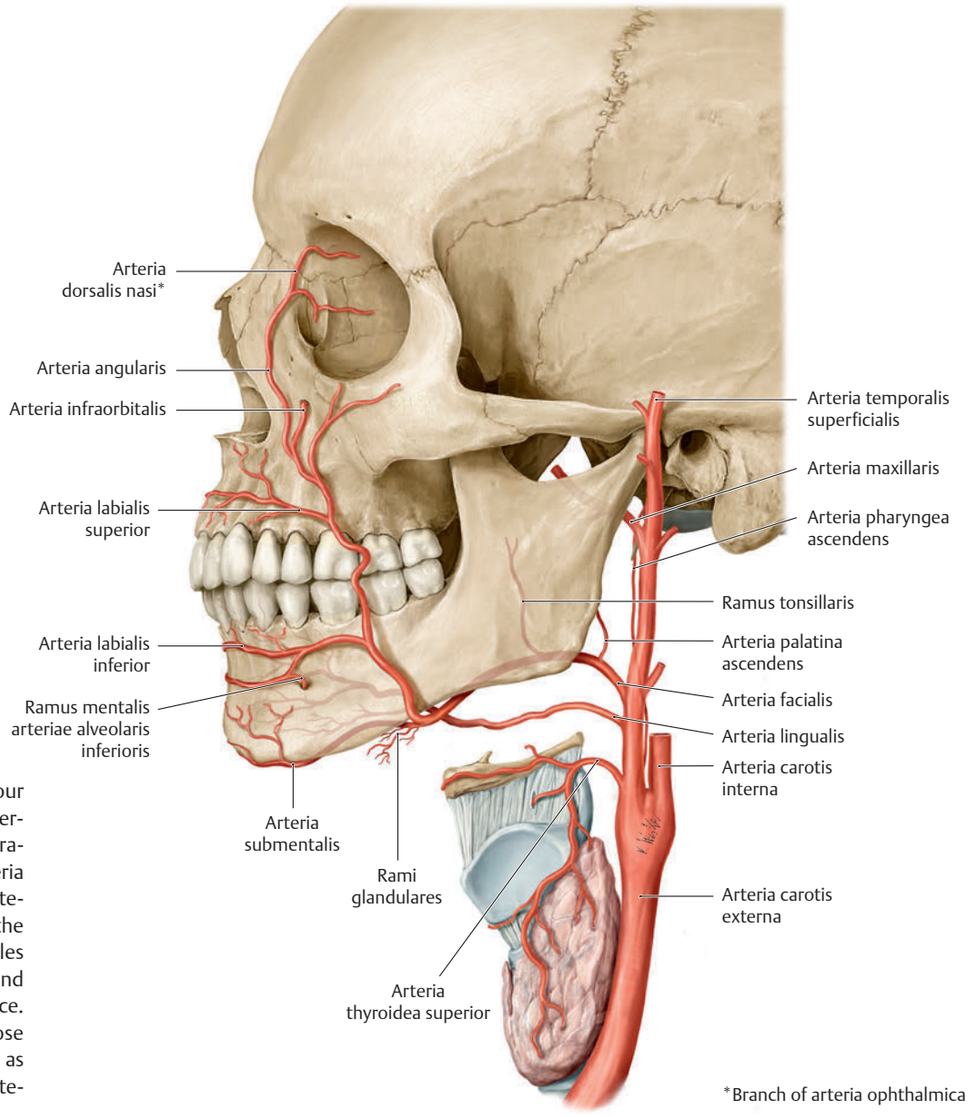


Fig. 3.6 **Arteria facialis and its branches**
Left lateral view. The arteria facialis has four cervical and four facial branches. The four cervical branches (arteria palatina ascendens, ramus tonsillaris, rami glandulares, and arteria submentalis) arise in the neck before the arteria facialis crosses the mandibula to reach the face. The four facial branches (arteriae labiales inferior and superior, ramus lateralis nasi, and arteria angularis) supply the superficial face. Branches of the arteria facialis anastomose with branches of the arteria carotis interna as well as other branches derived from the arteria carotis externa (see **Fig 3.12,** p. 59).

Table 3.4 **Branches of the arteria facialis**

Course: The arteria facialis arises from the arteria carotis externa in the trigonum caroticum of the neck. It then passes superiorly immediately deep to the venter posterior musculi digastrici and the musculus stylohyoideus. It runs along the glandula submandibularis then loops under and over the corpus mandibulae at the anterior border of the musculus masseter. It then runs anterosuperiorly across the cheek to the angulus oris and then continues superiorly along the side of the nose. It terminates as the arteria angularis along the medial aspect of the orbita. At its termination, the arteria angularis anastomoses with the arteria dorsalis nasi.

Branch	Region supplied
Cervical branches	
Arteria palatina ascendens	Pharyngeal wall, palatum molle, tuba auditiva, tonsillae palatinae, pharynx
Ramus tonsillaris	Tonsillae palatinae and pars oralis pharyngis
Rami glandulares	Glandula submandibularis
Arteria submentalis	Venter anterior musculi digastrici, musculus mylohyoideus, glandula submandibularis
Facial branches	
Arteria labialis inferior	Labium inferius
Arteria labialis superior	Labium superius; septum nasi (via ramus septi nasi)
Ramus lateralis nasi	Dorsum nasi
Arteria angularis	Radix nasi

Arteria Carotis Externa: Posterior Branches

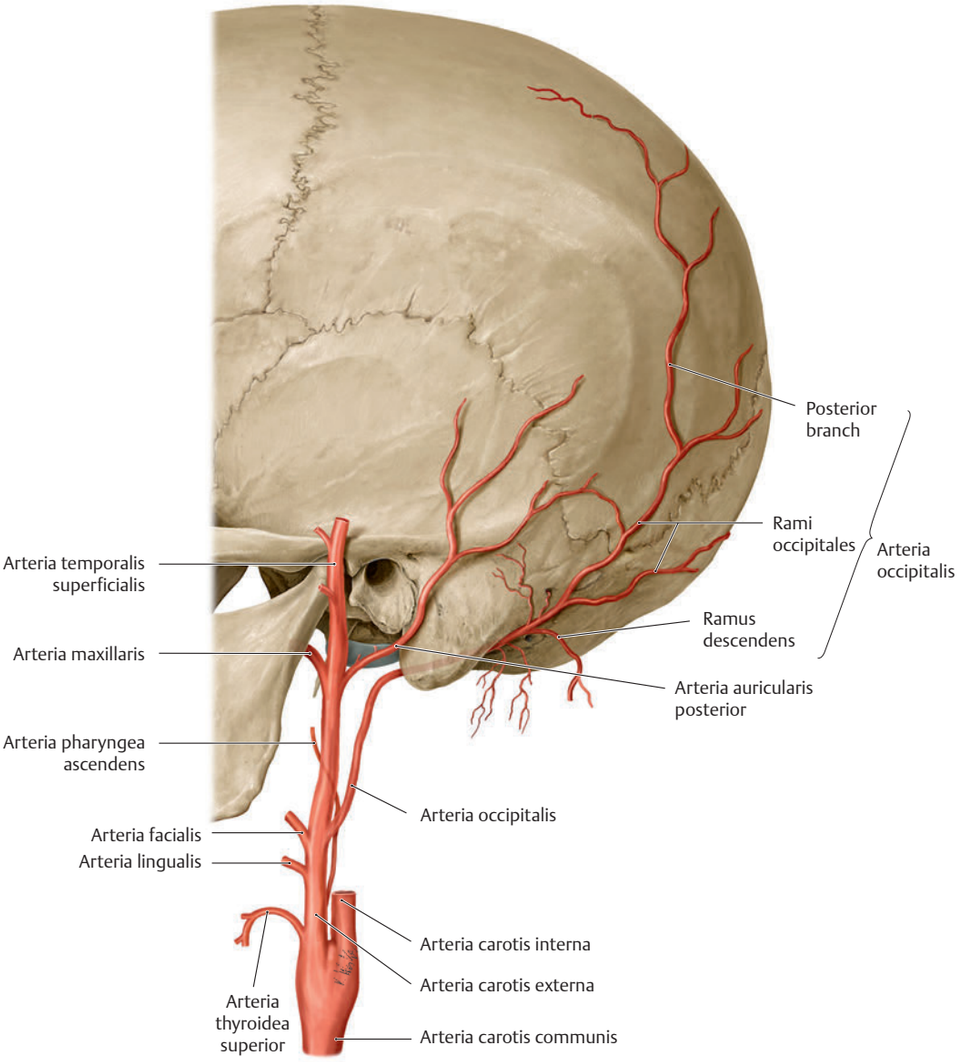


Fig. 3.7 **Branches of the arteria occipitalis**
The arteria occipitalis generally arises from the arteria carotis externa, just opposite the origin of the arteria facialis and just inferior to the venter posterior musculi digastrici (not shown). The artery passes posteriorly and near its origin is crossed laterally by the nervus hypoglossus (not shown). In its course to the posterior of the occiput, the arteria occipitalis passes lateral to the arteria carotis interna (at the same time that it is passing lateral to both the vena jugularis interna and cranial nerves CN X and CN XI--not shown). At the base of the skull, the arteria occipitalis passes medial to the processus mastoideus, travelling in the sulcus arteria occipitalis. Branches of the arteria occipitalis anastomose with branches of both the arteriae auricularis posterior and temporalis superficialis. On the posterior aspect of the cranium, the artery converges with the nervus occipitalis major (not shown). The arteria occipitalis gives rise to eight named branches (see **Table 3.5**).

Fig. 3.8 **Branches of the arteria auricularis posterior**
The arteria auricularis posterior arises from the arteria carotis externa as the last branch before the origin of its two terminal branches (arteriae maxillaris and temporalis superficialis). It arises superior to the venter posterior musculi digastrici. In its course the arteria auricularis posterior travels deep to the glandula parotidea and ascends along the lateral aspect of the processus styloideus of the os temporale. The artery then passes superiorly between the processus mastoideus and the posterior aspect of the auricula. It gives rise to 5 named branches (see **Table 3.5**).

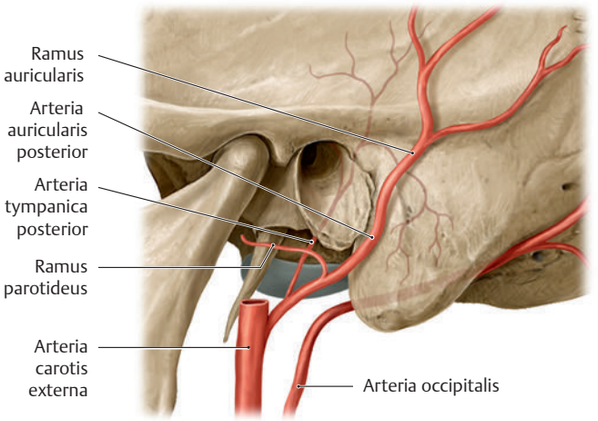


Table 3.5 **Branches of the arteriae occipitalis and auricularis posterior**

Branch	Further branches	Region supplied
Arteria occipitalis	Muscular branch	Regional muscles including venter posterior musculi digastrici and musculus stylohyoideus
	Rami sternocleidomastoidei	Musculus sternocleidomastoideus
	Ramus descendens	Posterior neck muscles
	Ramus meningeus	Structures internal and external to foramen jugulare
	Rami mastoidei	Cellulae mastoideae and dura
	Ramus auricularis	Auricula (medial side)
	Ramus occipitalis	Scalp of occipital region
	Arteria stylomastoidea*	Nervus facialis in canalis nervi facialis; cavitas tympani
Arteria auricularis posterior	Arteria stylomastoidea*	Nervus facialis in canalis nervi facialis; cavitas tympani
	Ramus occipitalis	Occiput
	Muscular branches	Venter posterior musculi digastrici and musculus stylohyoideus
	Ramus parotideus	Glandula parotidea
	Ramus auricularis	Posterior side of auricula

* The arteria stylomastoidea has a variable origin; it arises from the arteria occipitalis two thirds of the time and the arteria auricularis posterior one third of the time.

Arteria Carotis Externa: Terminal Branches (I)

The two terminal branches of the arteria carotis externa are the arteria maxillaris and the arteria temporalis superficialis. They divide within the substance of the glandula parotidea. The arteria maxillaris is the largest of the two terminal branches. It supplies the maxilla and mandibula (including the teeth), the muscles of mastication, the palatum, the nose, and the dura covering the brain.

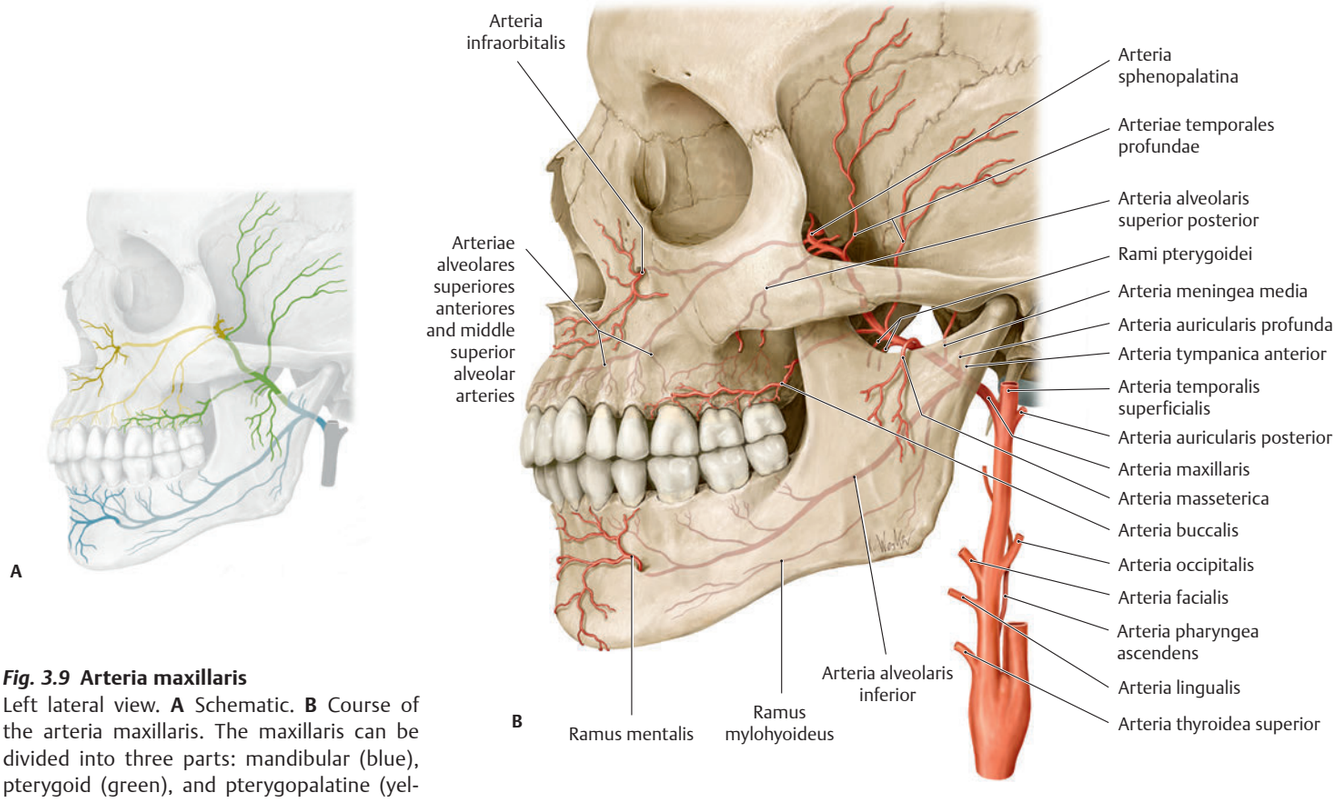


Fig. 3.9 **Arteria maxillaris**
Left lateral view. **A** Schematic. **B** Course of the arteria maxillaris. The maxillaris can be divided into three parts: mandibular (blue), pterygoid (green), and pterygopalatine (yellow). See **Table 3.6**.

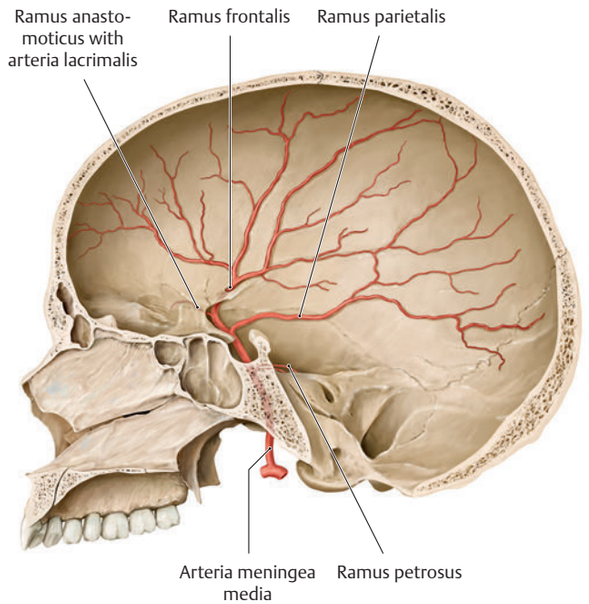


Fig. 3.10 **Arteria meningea media**
Medial view of right arteria meningea media. The arteria meningea media arises from the mandibular portion of the arteria maxillaris. It passes through the foramen spinosum into the fossa cranii media. Despite its name, it supplies blood not just to the meninges, but also to the overlying calvaria. Rupture of the arteria meningea media by head trauma results in an epidural hematoma (see **Fig. 4.58**, p. 103).

Table 3.6 **Branches of the arteria maxillaris**

Branch	Course	Distribution
Mandibular part (blue): Also known as the bony part or 1st part, this portion runs medial to the collum mandibulae and gives off 5 major branches, all of which enter bone.		
Arteria alveolaris inferior	Gives off a lingual and a ramus mylohyoideus before entering the foramen mandibulae to travel along the canalis mandibulae; it splits into 2 terminal branches (incisive and ramus mentalis)	Dentes molares and premolares mandibulares with associated gingiva, mandibula
	• Lingual branch	Lingual mucous membrane
	• Ramus mylohyoideus	Musculus mylohyoideus
	• Incisive branch	Dentes incisivi mandibulares
	• Ramus mentalis	Chin
Arteria tympanica anterior	Runs through the Fissura petrotympanica along with the chorda tympani	Auris media
Arteria auricularis profunda	Travels through the wall of the meatus acusticus externalis	Lateral membrana tympanica, skin of meatus acusticus externus
	• Branch to articulatio temporomandibularis	Articulatio temporomandibularis
Arteria meningea media	Runs through the foramen spinosum to the fossa cranii media	Bones of the cranial vault, dura of fossae cranii anterior and mediae
Ramus accessorius arteriae meningeae mediae	Runs through the foramen ovale to the fossa cranii media	Musculi pterygoidei medialis and laterales, tensor veli palatini, sphenoid bone, dura, ganglion trigeminale
Pterygoid part (green): Also known as the muscular part or 2nd part, this portion runs between the musculi temporalis and musculi. It gives off 5 major branches, all of which supply muscle.		
Arteria masseterica	Runs through the incisura mandibulae (notch)	Musculus masseter, articulatio temporomandibularis
Rami temporales profundae	Consist of anterior, middle, and posterior branches, which course deep to the musculus temporalis	Musculus temporalis
Rami pterygoidei (lateral part)	Runs directly to the musculus pterygoideus lateralis	Musculus pterygoideus lateralis
Rami pterygoidei (medial part)	Runs directly to the musculus pterygoideus medialis	Musculus pterygoideus medialis
Arteria buccalis	Accompanies the nervus buccalis	Buccal mucosa and skin, musculus buccinator
Pterygopalatine part or 3rd part (yellow): This portion runs through the fissura pterygomaxillaris to enter the fossa pterygopalatinum. It gives off 6 major branches, which accompany the branches of the nervus maxillaris (CN V_2).*		
Arteria alveolaris superior posterior	Runs through the fissura pterygomaxillaris; may arise from the arteria infraorbitalis	Dentes molares and premolares maxillares, with associated gingiva; sinus maxillaris
Arteria infraorbitalis	Runs through the fissura orbitalis inferior into the orbita, where it runs along the sulcus infraorbitalis and canalis infraorbitalis, exiting onto the face via the foramen infraorbitale	Cheek, upper lip, nose, lower eyelid
	• Arteriae alveolares superior anterior and middle superior alveolar aa.	Dentes maxillares and sinus maxillaris
Arteria palatina descendens	• Arteria palatina major: runs via the canalis palatinus major; in the canal it gives off several arteriae palatinae minores; continues through foramen palatinum majus onto palatum durum	Roof of palatum durum, cavitas nasi (meatus inferior), maxillary gingiva
	• Arteriae palatinae minores: runs via the foramen palatinum minus	Palatum molle
	• Anastomosing branch: runs via the canalis incisivus; joins with the arteria sphenopalatina	Septum nasi
Arteria sphenopalatina	Runs via the foramen sphenopalatinum to the cavitas nasi; gives off arteriae nasales posteriores laterales, then travels to the septum nasi, where it terminates as rami septales posteriores	
	• Arteriae nasales posteriores laterales: anastomose with the arteriae ethmoidales and nasal branches of the arteria palatina major	Nasal air sinuses (sinus frontalis, sinus maxillaris, cellulae ethmoidales, and sinus sphenoidalis)
	• Rami septales posteriores: anastomose with the arteriae ethmoidales on the septum nasi	Conchae nasi and septum nasi
Arteria canalis pterygoidei	Runs through the canalis pterygoideus	Tuba auditiva, cavitas tympani, upper pharynx
Rami pharyngei	Runs through the canalis palatovaginalis	Pars nasalis pharyngis, sinus sphenoidalis, and tuba auditiva; mucosa of cavitas nasi

*All branches are named for the nerve they travel with except for the arteria sphenopalatina, which travels with the nervus nasopalatinus.

Arteria Carotis Externa: Terminal Branches (II) & Anastomoses

Fig. 3.11 **Arteria temporalis superficialis**
Left lateral view. The arteria temporalis superficialis is the second of the two terminal branches of the arteria carotis externa. Particularly in elderly or cachectic patients, the often tortuous course of the frontal branch of this vessel can be easily traced across the temple. Temporal arteritis (giant cell arteritis, cranial arteritis) is an inflammatory condition affecting the medium-sized arteries that supply the temple region, scalp, eyes, and nervi optici. The average age of onset of this condition is 70 years and it affects women twice as commonly as men. Symptoms may begin as general malaise and progress rapidly to headaches, tenderness of the scalp, severe pain in the temple region, transient blurred vision, diplopia (double vision), ptosis (drooping eyelid), neck pain, and jaw claudication (pain on jaw manipulation, e.g., during eating, due to ischemia of the musculus masseter). It is diagnosed by blood tests that indicate an inflammatory process is ongoing and by biopsy of the arteria temporalis superficialis (definitive test). If not treated promptly (usually before biopsy results confirm the condition), then it may cause painless loss of vision in the affected eye that is usually permanent. Having temporal arteritis also increases the risk of stroke and aortic aneurysm. Treatment is with corticosteroids, often long-term.

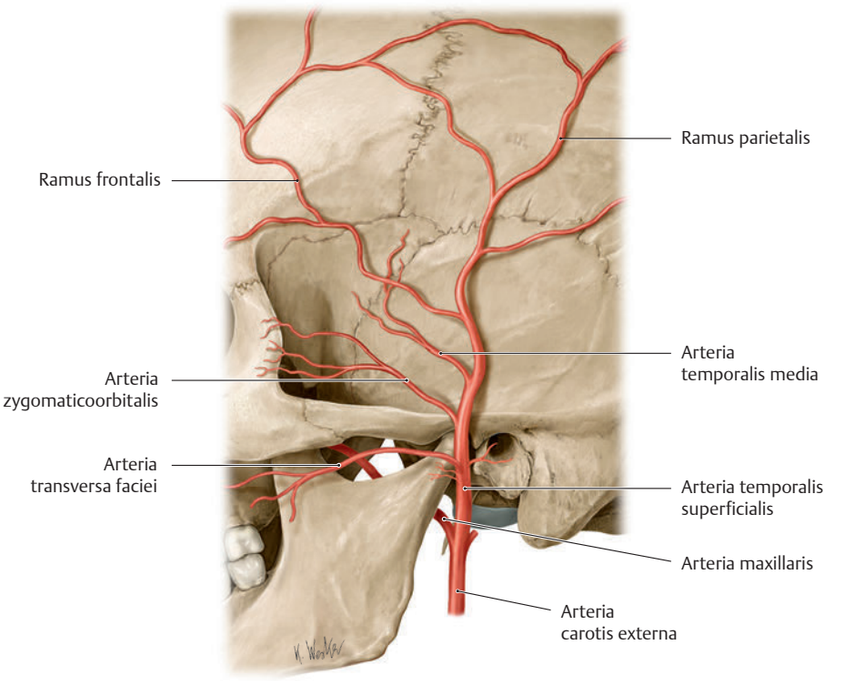


Table 3.7 **Branches of the arteria temporalis superficialis**

Branch	Further branches	Region supplied
Arteria temporalis superficialis	Arteria transversa faciei	Soft tissues below arcus zygomaticus, glandula parotidea, musculus masseter
	Rami auriculares anteriores	Meatus acusticus externa, anterior area of auricula
	Arteria temporalis media	Musculus temporalis
	Arteria zygomaticoorbitalis	Lateral external orbital wall and musculus orbicularis oculi
	Rami frontales	Scalp of forehead
	Rami parietales	Scalp of vertex

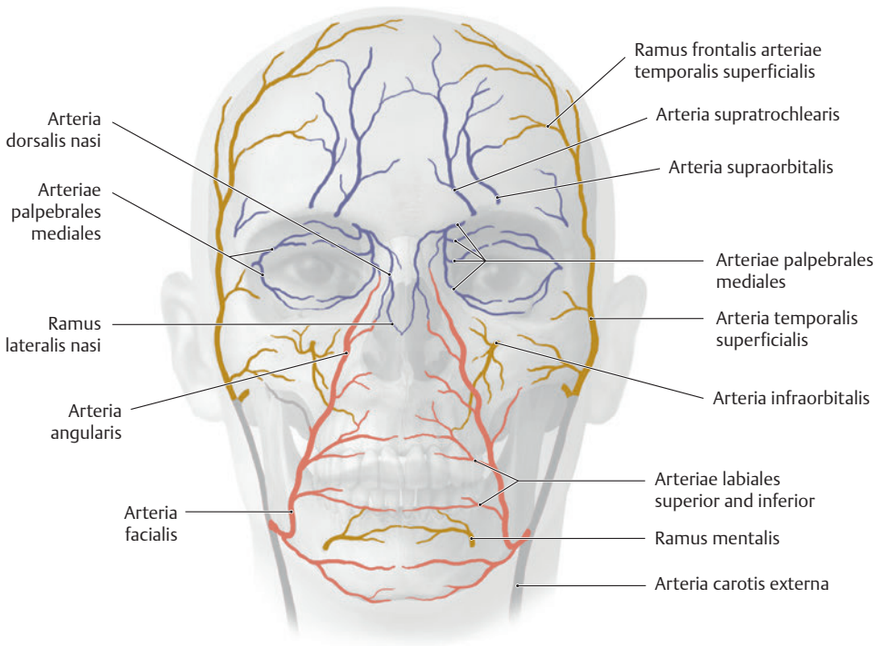


Fig. 3.12 **Anastomoses of the arteriae carotides externa and interna**

Branches of the arteria carotis externa (e.g., arteria facialis [red], arteria temporalis superficialis [yellow], and arteriae infraorbitales [yellow]) and the arteria carotis interna (e.g., arteriae dorsalis nasi and supraorbitalis [purple]) anastomose in certain facial regions to ensure blood flow to the face and head. Anastomoses occur between the arteria angularis and arteria dorsalis nasi and between the arteria temporalis superficialis and arteria supraorbitalis. Due to the extensive arterial anastomoses, facial injuries tend to bleed profusely but also heal quickly.

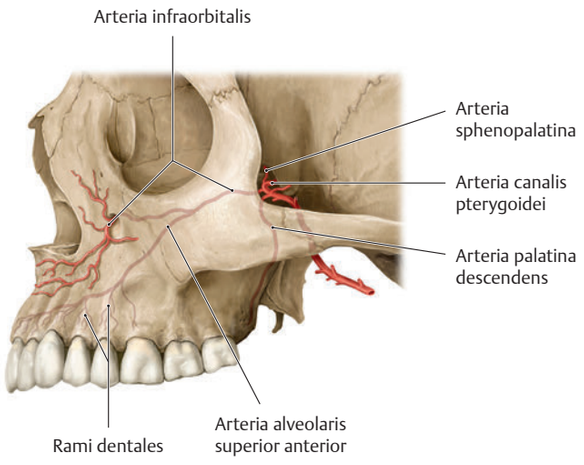


Fig. 3.13 **Arteria infraorbitalis**

Left lateral view. The arteria infraorbitalis arises from the pterygopalatine part of the arteria maxillaris (a terminal branch of the arteria carotis externa), and the arteria supraorbitalis (not shown) arises from the arteria carotis interna (via the arteria ophthalmica). These vessels therefore provide a path for potential anastomosis between the arteriae carotides interna and externa on the face.

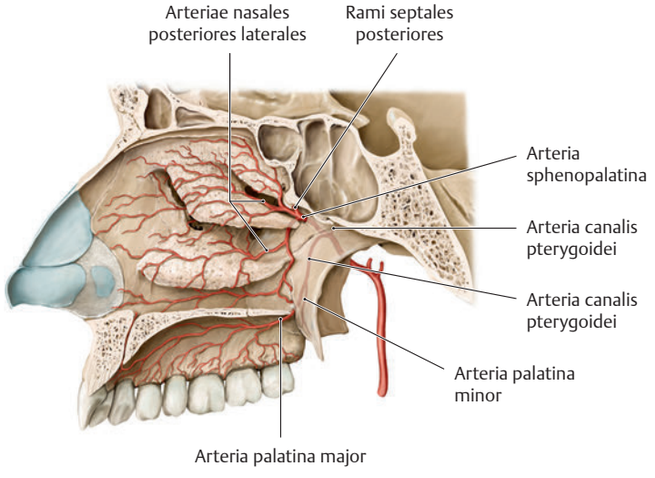


Fig. 3.14 **Arteria sphenopalatina**

Medial view of right nasal wall and right arteria sphenopalatina. The arteria sphenopalatina enters the cavitas nasi through the foramen sphenopalatinum. The anterior portion of the septum nasi contains a highly vascularized region (Kiesselbach's area), which is supplied by both the rami septales posteriores of the arteria sphenopalatina (arteria carotis externa) and the rami septales anteriores of the arteria ethmoidalis anterior (arteria carotis interna via arteria ophthalmica). When severe nasopharyngeal bleeding occurs, it may be necessary to ligate the arteria maxillaris in the fossa pterygopalatina.

Arteria Carotis Interna

Fig. 3.15 **Overview of the arteria carotis interna**

The arteria carotis interna branches from the arteria carotis communis at the level of the bifurcatio carotidis (C4 vertebral level). Its extracranial part gives off no branches. The internal part has four anatomical parts that supply blood to the truncus encephali and encephalon (see **Fig 3.16**).

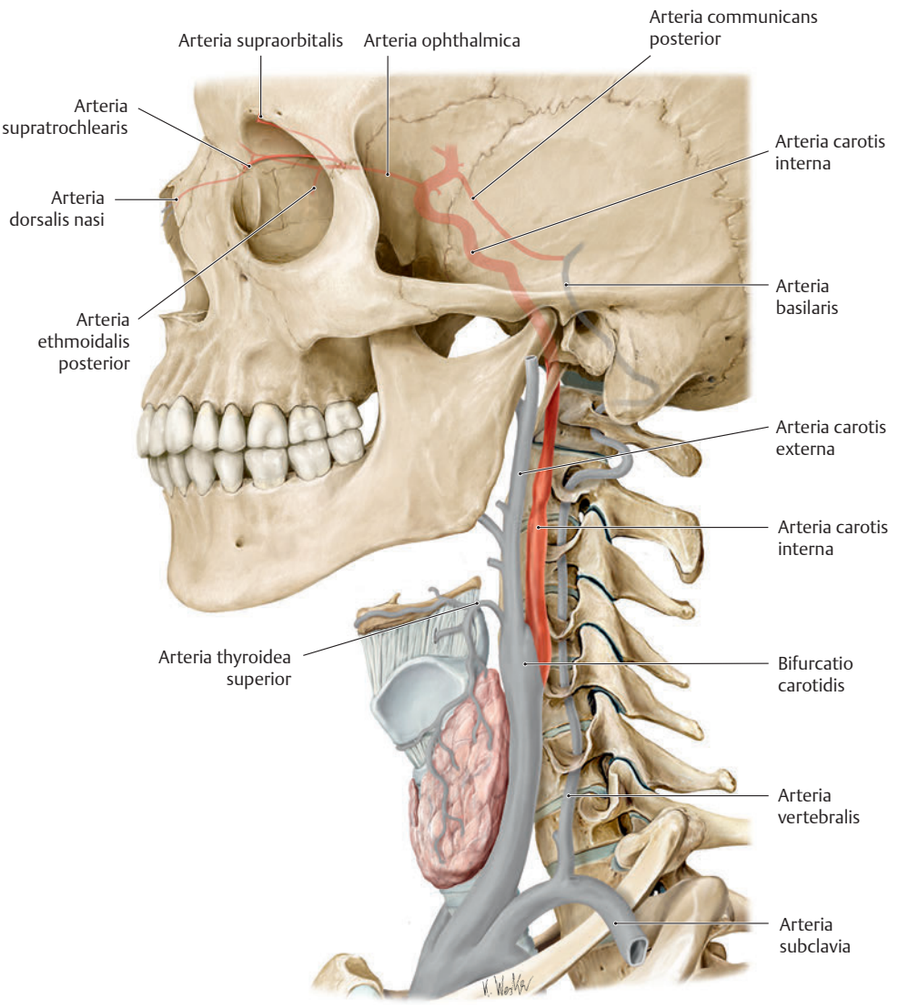
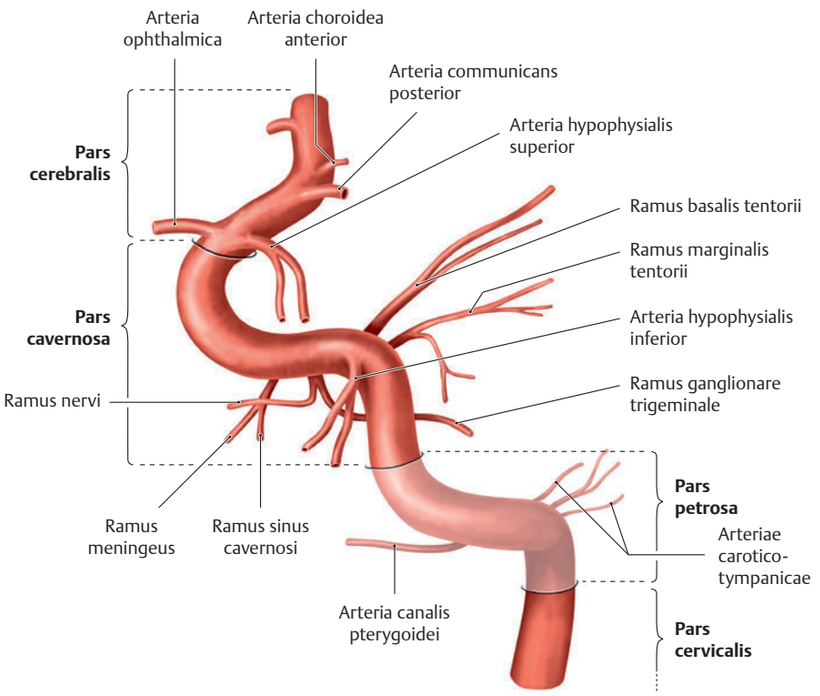


Fig. 3.16 **Subdivisions of the arteria carotis interna**

Anatomical segments of the arteria carotis interna and their branches. The Arteria carotis interna is distributed chiefly to the brain but also supplies extracerebral regions of the head. It consists of four parts (listed from bottom to top):

- Pars cervicalis
- Pars petrosa
- Pars cavernosa
- Pars cerebralis

The pars petrosa of the arteria carotis interna (traversing the canalis caroticus) and the pars cavernosa (traversing the sinus cavernosus) have a role in supplying extracerebral structures of the head. They give off additional small branches that supply local structures and are usually named for the areas they supply. Of the branches not supplying the encephalon, of special importance is the arteria ophthalmica, which arises from the pars cerebralis of the arteria carotis interna. *Note:* The arteria ophthalmica forms an anastomosis with the arteria canalis pterygoidei derived from the arteria maxillaris.



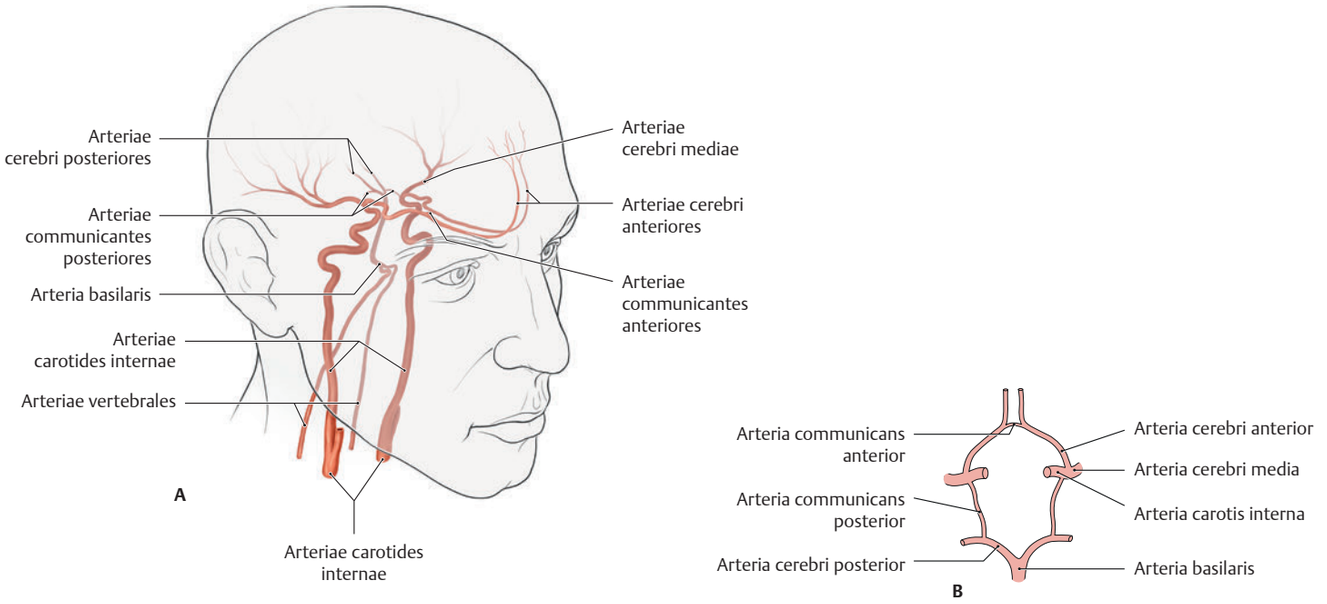


Fig. 3.17 **Blood supply to the encephalon**
A Schematic of circulus arteriosus cerebri in situ. **B** Schematic of isolated circulus arteriosus cerebri.
The encephalon is supplied by four arteries that leave the root of the neck separately, the left and right arteria carotis interna and the left and right arteriae vertebrales. However, the arteriae vertebrales converge to form the arteria basilaris and so only three arteries reach the base of the brain, where they form the circulus arteriosus cerebri. The circulus arteriosus cerebri is a means by which the encephalon can receive blood when one or more of its major arterial contributors becomes narrowed or blocked, for example, by an embolus, possibly preventing ischemic stroke.

Table 3.8 **Contribution of the arteria carotis interna to the blood supply of the eye, nose, face, and surrounding areas**

Course: The arteria ophthalmica branches from the arteria carotis interna (ICA) just after the ICA passes through the sinus cavernosus. It runs along the medial side of the processus clinoideus anterior passing anteriorly through the canalis opticus with the nervus opticus. It then courses in the medial wall of the orbita. The two terminal branches of the arteria ophthalmica are the arteria dorsalis nasi and supratrochlearis.

Origin	Artery	Region supplied
Arteria ophthalmica (branch of arteria carotis interna)	*Ocular branches*	
	Arteria centralis retinae	Retina
	Arteriae ciliares anteriores	Bulbus oculi
	Arteriae ciliares posteriores longae and breves	Bulbus oculi
	Orbital branches	
	Arteria lacrimalis	Glandulae lacrimales, palpebrae, and conjunctiva
	Arteriae musculares	Extraocular muscles
	Arteriae palpebrales mediales	Palpebrae
	Arteria ethmoidalis posterior	Cellulae ethmoidales, posterosuperior septum nasi, part of sinus sphenoidalis and meninges
	Arteria ethmoidalis posterior	Cellulae ethmoidales, anterosuperior septum nasi, lateral nasal wall, and fossa cranii anterior
	Arteria supratrochlearis	Muscles and skin of the medial forehead, and sinus frontalis
	Arteria supraorbitalis	Muscles and skin of the forehead, and sinus frontalis
	Ramus meningeus	Fossa cranii media
	Arteria dorsalis nasi	Region along the bridge of the nose

Veins of the Head and Neck: Overview

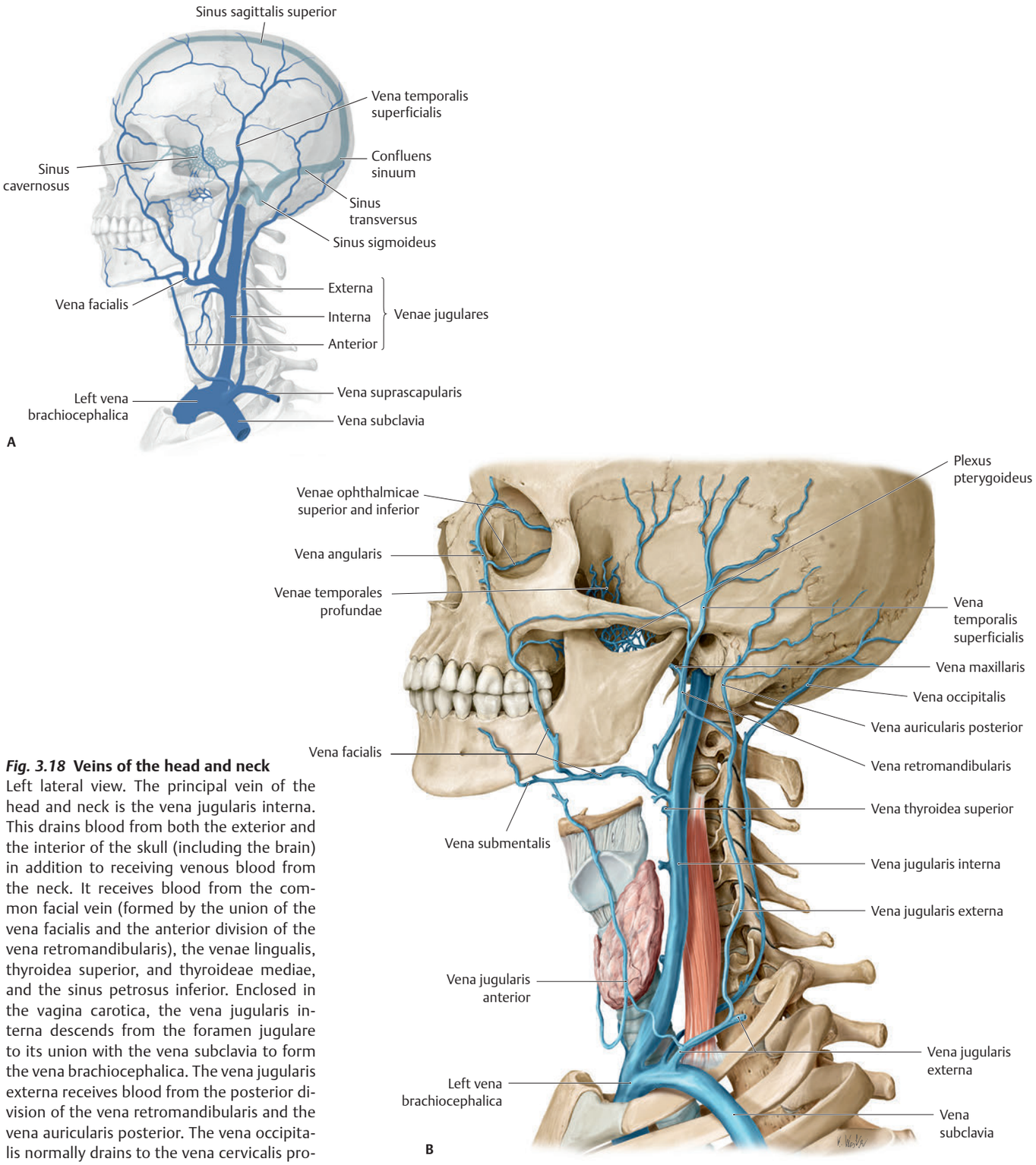


Fig. 3.18 **Veins of the head and neck**
Left lateral view. The principal vein of the head and neck is the vena jugularis interna. This drains blood from both the exterior and the interior of the skull (including the brain) in addition to receiving venous blood from the neck. It receives blood from the common facial vein (formed by the union of the vena facialis and the anterior division of the vena retromandibularis), the venae lingualis, thyroidea superior, and thyroideae mediae, and the sinus petrosus inferior. Enclosed in the vagina carotica, the vena jugularis interna descends from the foramen jugulare to its union with the vena subclavia to form the vena brachiocephalica. The vena jugularis externa receives blood from the posterior division of the vena retromandibularis and the vena auricularis posterior. The vena occipitalis normally drains to the vena cervicalis profunda. The vena subclavia in the thorax can be catheterized in acutely ill or chronically ill patients to provide a fast and stable route for administering medication, fluids, and nutrition, and for measuring central oxygen saturation and central venous pressure (to quantify their fluid status). This is called *central venous catheterization* or a "central line." Other large veins in the neck (e.g., the vena jugularis interna), thorax (e.g., the vena axillaris), or the groin (e.g., the vena femoralis) can also be catheterized in this way.

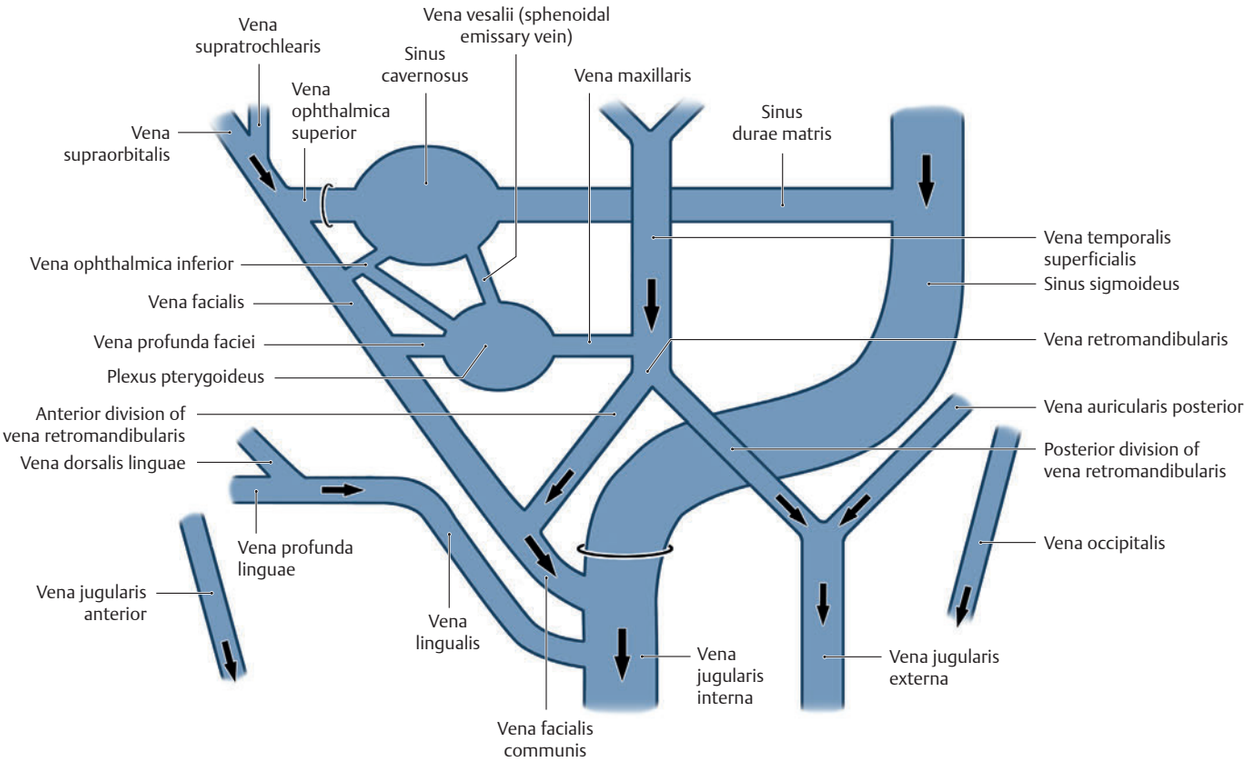


Fig. 3.19 **Veins of the head: overview**
The superficial veins of the head communicate with each other and with the sinus durae matris via the deep veins of the head (plexus pterygoideus and sinus cavernosus). The plexus pterygoideus connects the vena facialis and the vena retromandibularis (via the vena profunda faciei and vena maxillaris, respectively). The sinus cavernosus connects the vena facialis to the sinus sigmoideus (via the venae ophthalmicae and the sinus petrosi, respectively).

Sinus cavernosus thrombosis is the formation of a thrombus (blood clot) in the sinus cavernosi. It usually occurs secondary to an infection in the nasal sinuses, teeth, ears, eyes, or the skin of the face. The infective organism is typically staphylococcus aureus, but it can also be caused by streptococci, pneumococci, and fungi. Signs and symptoms include headache, eye pain, exophthalmos (bulging eyeball), ptosis (drooping eyelid), vision loss, sluggish pupillary responses, and limitation of movement of the eye due to paralysis of the nervi oculomotorius, trochlearis and abducens. It may progress to meningitis or sepsis.

Table 3.9 **Venous drainage of the head and neck**

Vein	Location	Tributaries	Region drained
Vena jugularis interna	Within vagina carotica	Common facial v. — Vena facialis — Vena retromandibularis, anterior division Venae pharyngeae Vena lingualis Venae thyroideae superior and mediae	Skull, anterior and lateral face, cavitas oris, external pharynx, neck
		Sinus sigmoideus and Sinus petrosus inferior	Interior of skull (including encephalon)
Vena jugularis externa	Within superficial fascia cervicis	Vena retromandibularis, posterior division	Lateral skull
		Vena auricularis posterior	Occiput
Vena jugularis anterior		Superficial veins in submandibular region	Anterior neck

Superficial Veins of the Head

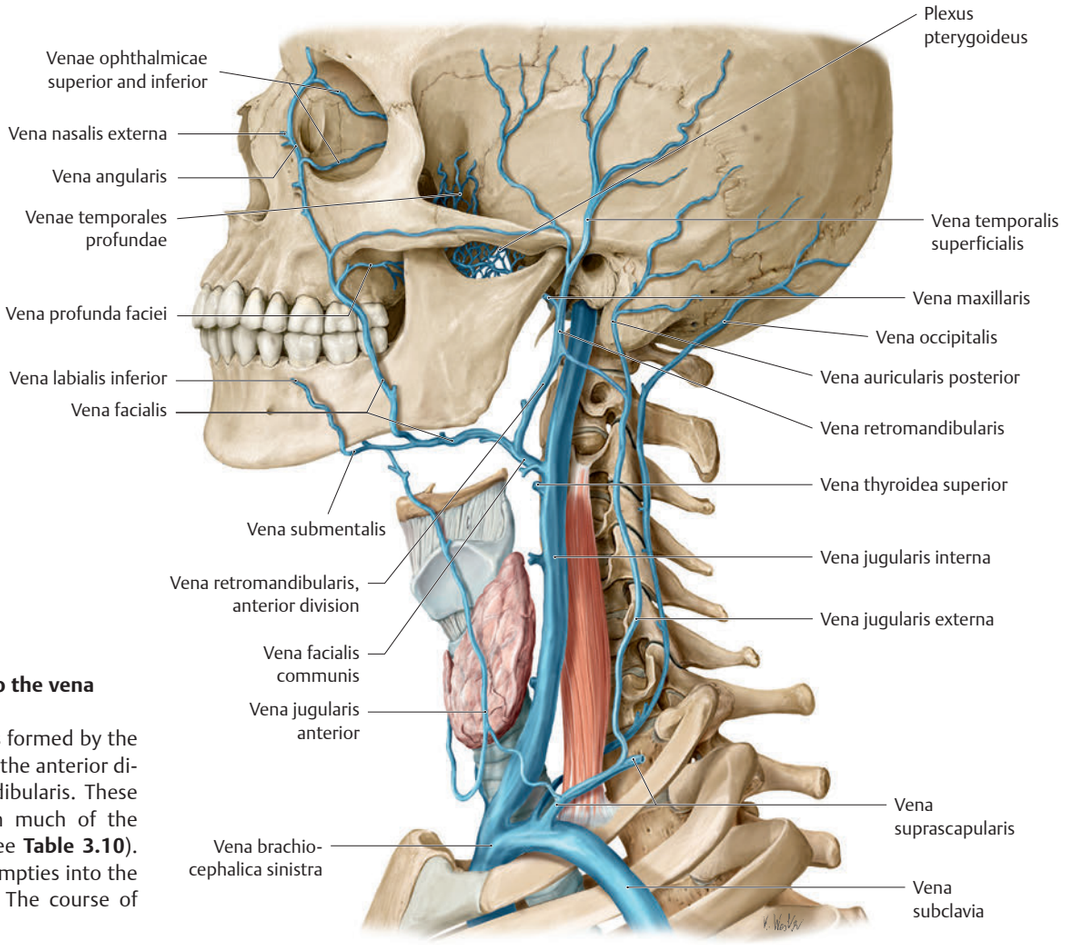


Fig. 3.20 **Venous drainage to the vena facialis communis**
The vena facialis communis is formed by the union of the vena facialis and the anterior division of the vena retromandibularis. These tributaries combine to drain much of the face, eye, and cavitas oris (see **Table 3.10**). The vena facialis communis empties into the vena jugularis interna. *Note:* The course of veins is highly variable.

Table 3.10 **Tributaries of the vena facialis communis**

Course: tributaries of the vena facialis communis course parallel to the branches of the arteria maxillaris

Tributary	Further tributaries	Region drained
Vena facialis	Vena angularis*	Anterior scalp, forehead, upper and lower palpebrae, conjunctiva, root of the nose, sinus cavernosus (via communication with vena ophthalmica)
	Vena nasalis externa	External nose
	Vena labialis superior	Labium superius
	Vena labialis inferior	Labium inferius
	Vena profunda faciei (from plexus pterygoideus)	Contributes to drainage from plexus pterygoideus (see vena maxillaris below)
	Venae parotideae	Parotid region
	Vena palatina externa	Palatum molle and tonsillae
	Vena submentalis	Mylohyoid region
Vena retromandibularis, anterior division	Vena maxillaris (from plexus pterygoideus)	Orbita and oculus, muscles of mastication, musculi faciei, buccal mucosa and skin, palatum durum, palatum molle, teeth and their associated gingivae, glandulae submandibulares, sublinguales, and parotideae, articulatio temporomandibularis, chin, sinus paranasales (frontalis, maxillaris, ethmoidalis, and sphenoidalis), conchae nasi, septum nasi, meatus acusticus externus, membrana tympanica
	Vena temporalis superficialis	Anterior auricula, temple region, and scalp

* The vena angularis is formed by the confluence of the venae supratrochlearis and subraorbitalis

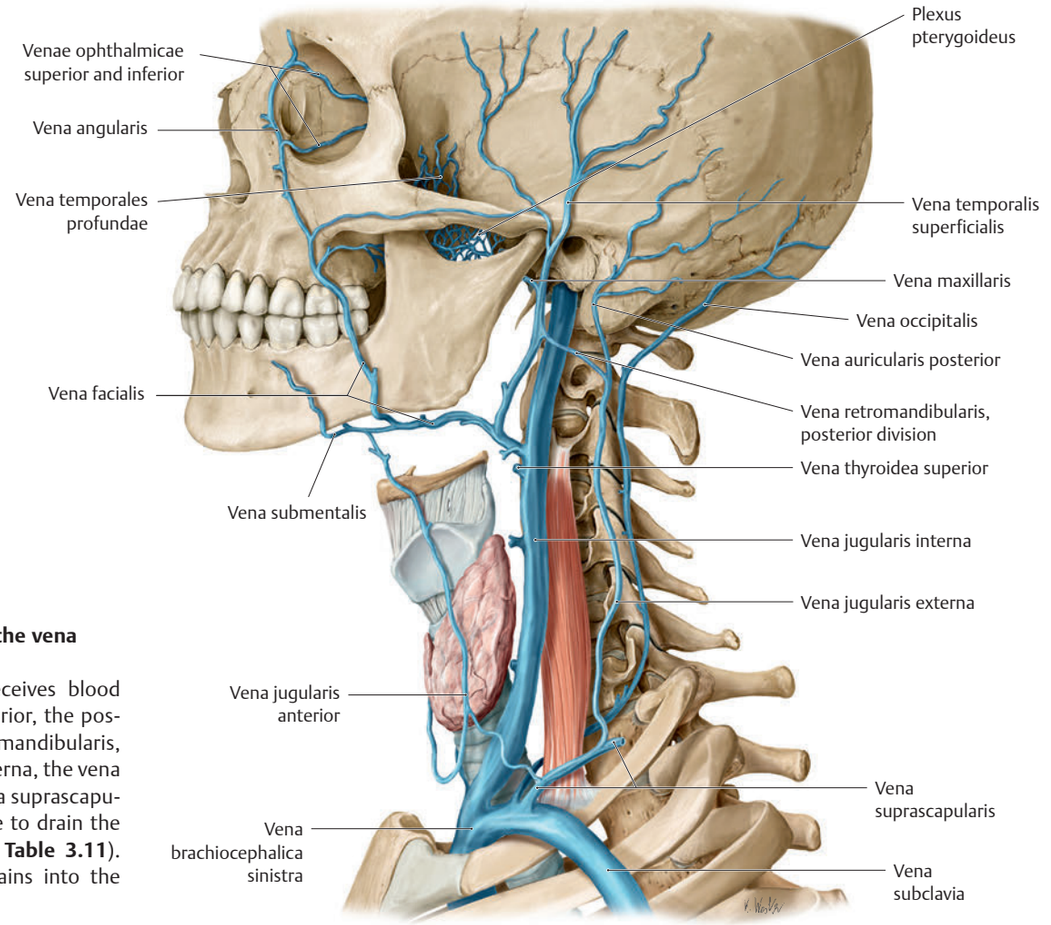


Fig. 3.21 **Venous drainage to the vena jugularis externa**

The vena jugularis externa receives blood from the vena auricularis posterior, the posterior division of the vena retromandibularis, the posterior vena jugularis externa, the vena transversa cervicis, and the vena suprascapularis. These tributaries combine to drain the face and superficial neck (see **Table 3.11**). The vena jugularis externa drains into the vena subclavia.

Table 3.11 **Tributaries of the vena jugularis externa**

Course: Arises at the confluence of vena auricularis posterior and the posterior division of the vena retromandibularis within the substance of the glandula parotidea, at the level of the angulus mandibulae. It travels inferiorly within superficial fascia cervicalis to drain into the vena subclavia.

Tributary	Further tributaries	Region drained
Vena auricularis posterior		Posterior auricula, meatus acusticus externus, membrana tympanica, posterior scalp, glandula parotidea
Vena retromandibularis, posterior division	Vena maxillaris	Orbita and oculus, muscles of mastication, musculi faciei, buccal mucosa and skin, palatum durum, palatum molle, teeth and their associated gingivae, glandulae submandibularis, sublingualis, and parotidea, articulatio temporomandibularis, chin, sinus paranasales (frontalis, maxillaris, ethmoidalis, and sphenoidalis), conchae nasi, septum nasi, meatus acusticus internus, membrana tympanica
	Vena temporalis superficialis	Anterior auricula, superficial face
Posterior vena jugularis externa		Skin and superficial muscles in the upper and back part of the neck
Vena transversa cervicis		Musculus trapezius and surrounding tissue
Vena suprascapularis		Musculi supraspinatus and infraspinatus; shoulder joint
Vena jugularis anterior		Superficial parts of the anterior neck

Deep Veins of the Head

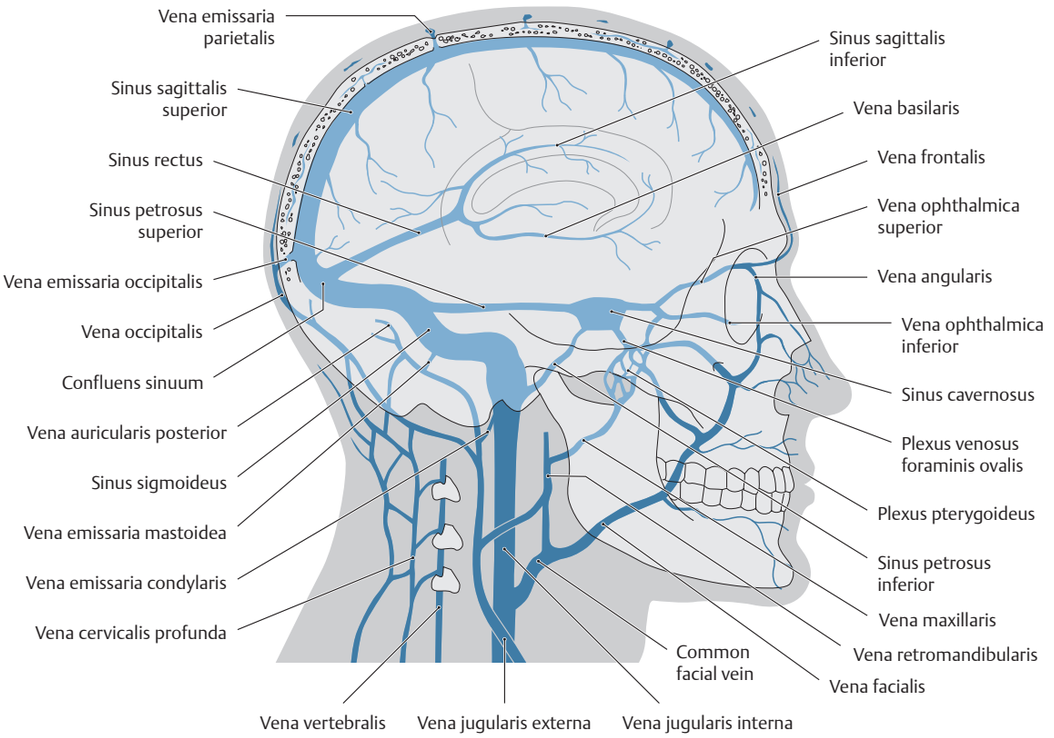


Fig. 3.22 **Venous drainage of the head**
The superficial veins of the head have extensive connections with the deep veins of the head and the sinus durae matris. The meninges and encephalon are drained by the sinus durae matris, which lie within the skull. Venae emissariae connect the superficial veins of the skull directly to the sinus durae matris. In addition, the deep veins of the head (e.g., plexus pterygoideus) are intermediaries between the superficial veins of the face and the sinus venosi durae matris.

Table 3.12 **Venous anastomoses as portals of infection**

The extracranial veins of the head are connected to the deep veins and sinus durae matris. Patients who sustain midfacial fractures may bleed profusely due to the extensive venous anastomoses. Because the veins are generally valveless, extracranial bacteria may migrate to the deep veins, causing infections (e.g., bacteria from boils on the upper lip or nose may enter the vena angularis and travel to the sinus cavernosus). Bacteria in the sinus cavernosus may cause thrombosis.

Extracranial vein	Connecting vein	Venous sinus
Vena angularis	Vena ophthalmica superior	Sinus cavernosus
Venae of tonsilla palatina	Plexus pterygoideus, vena ophthalmica inferior	
Vena temporalis superficialis	Vena emissaria parietalis	Sinus sagittalis superior
Vena occipitalis	Vena emissaria occipitalis	Sinus transversus, confluens sinuum
Vena auricularis posterior	Vena emissaria mastoidea	Sinus sigmoideus
Plexus venosus vertebralis externus	Vena emissaria mastoidea	

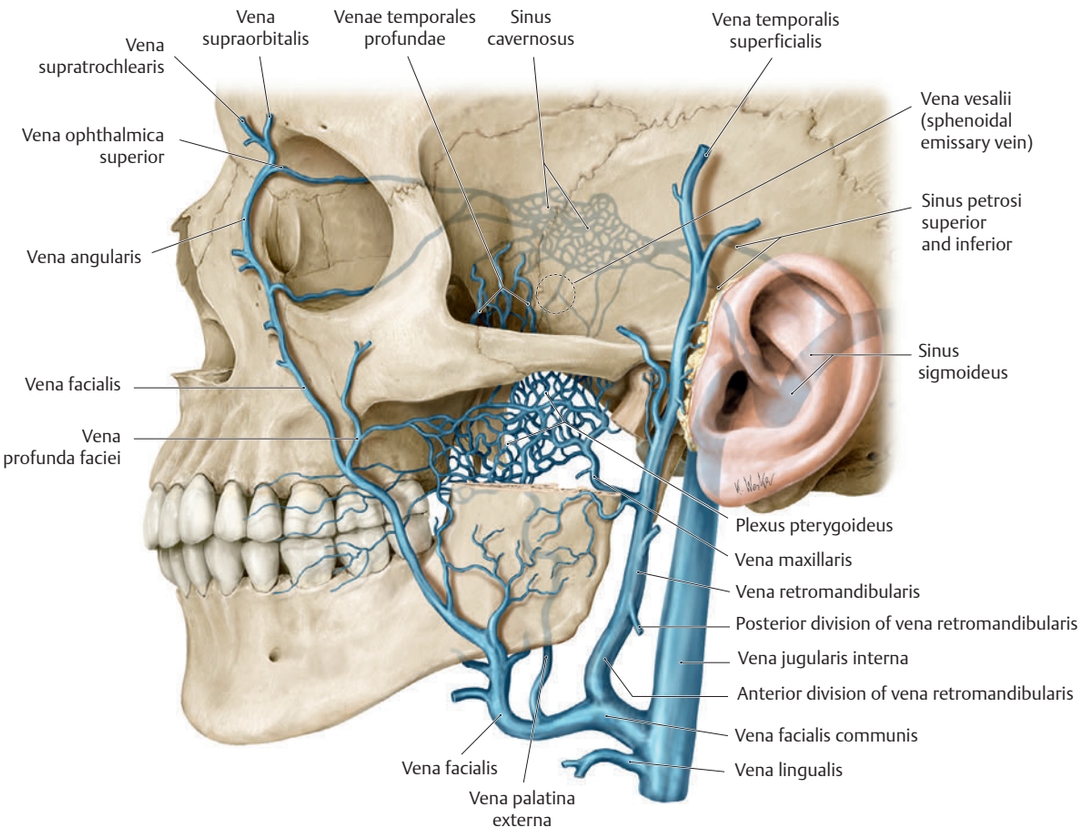


Fig. 3.23 **Deep veins of the head**
Left lateral view. The plexus pterygoideus is a venous network situated behind the ramus mandibulae and embedded in the musculi pterygoidei. Because the veins of the face have no valves (small valves may be present but are generally nonfunctional), the movement of the musculi pterygoidei forces blood from the plexus pterygoideus into the venae jugulares. The plexus pterygoideus is linked to the vena facialis via the vena profunda faciei and to the vena retromandibularis via the vena maxillaris. The plexus is also linked to the sinus cavernosus via the vena emissaria. The sinus cavernosus receives blood from the venae ophthalmicae superior and inferior.

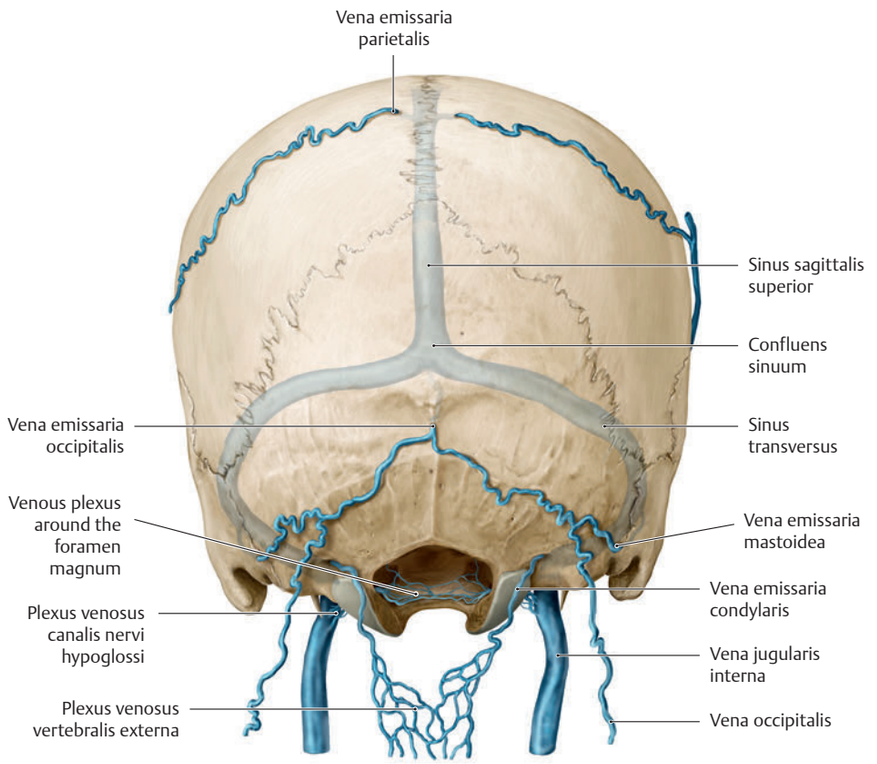


Fig. 3.24 **Veins of the occiput**
Posterior view. The sinus durae matris are the series of venous channels that drain the encephalon. The superficial veins of the occiput communicate with the sinus durae matris by way of the venae emissariae. The venae emissariae enter a similarly named foramen to communicate with the sinus durae matris.

Lymphatics of the Head & Neck (I)

A distinction is made between regional lymph nodes, which are associated with a particular organ or region and constitute their primary filtering stations, and collecting lymph nodes, which usually receive lymph from multiple regional lymph node groups. Lymph from the head and neck region, gathered in scattered regional nodes, flows through its system of deep cervical collecting lymph nodes into the right and left trunci jugulares, each closely associated with its corresponding vena jugularis interna. The truncus jugularis on the right side drains into the ductus lymphaticus dexter, which terminates at the right jugulosubclavian junction. The truncus jugularis on the left side terminates at the ductus thoracicus, which empties into the left jugulosubclavian junction (see **Fig. 12.16**).

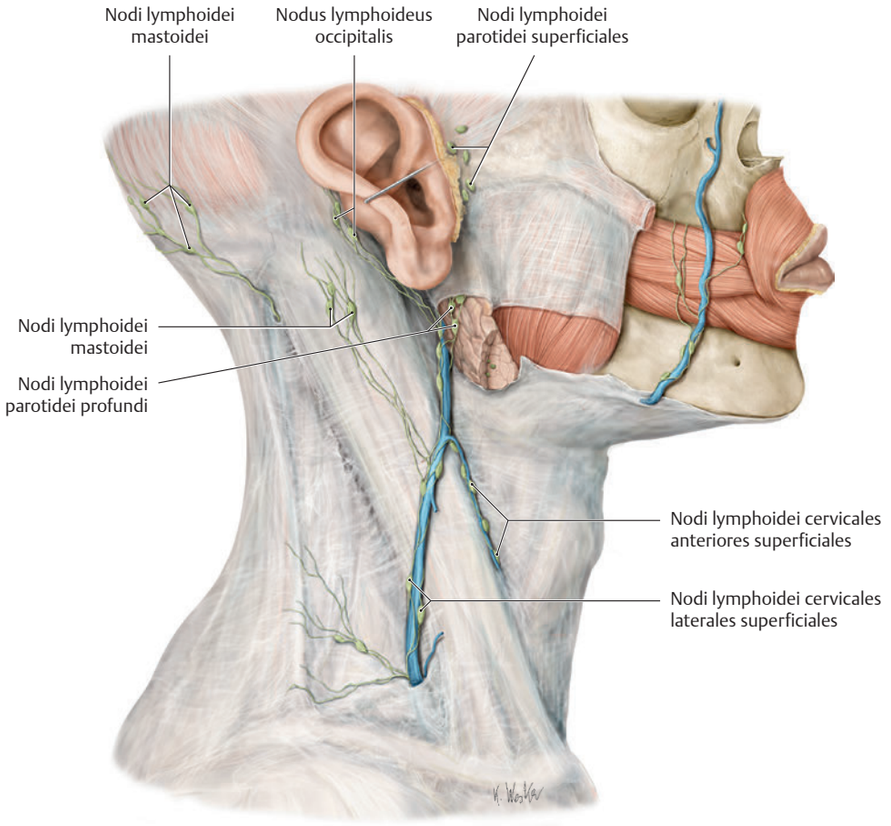


Fig. 3.25 **Nodi lymphoidei cervicales superficiales**
Right lateral view. Enlarged nodi lymphoidei cervicales are a common finding at physical examination. The enlargement of nodi lymphoidei cervicales may be caused by inflammation (usually a *painful* enlargement) or neoplasia (usually a *painless* enlargement) in the area drained by the nodes. The nodi lymphoidei cervicales superficiales are primary drainage locations for lymph from adjacent areas or organs.

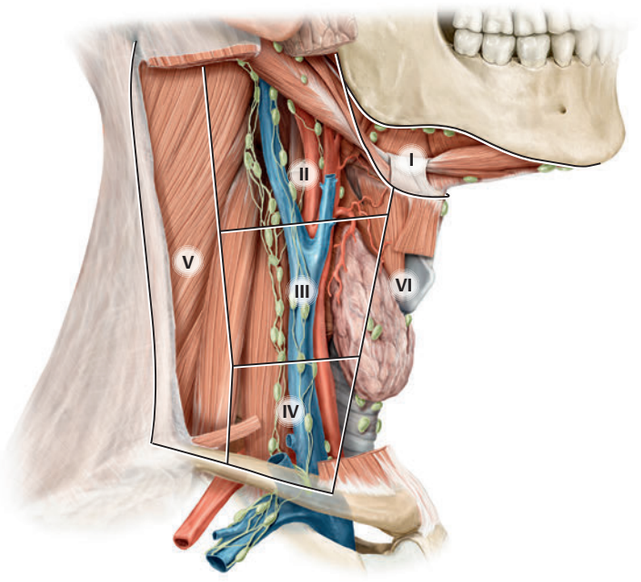


Fig. 3.26 **Nodi lymphoidei cervicales profundi**
Right lateral view. The deep lymph nodes in the neck consist mainly of collecting nodes. They have major clinical importance as potential sites of metastasis from head and neck tumors. Affected nodi lymphoidei cervicales profundi may be surgically removed (neck dissection) or may be treated by regional irradiation. For this purpose, the American Academy of Otolaryngology—Head and Neck Surgery has grouped the deep cervical lymph nodes into six levels (Robbins 1991):

I Nodi lymphoidei submentales and submandibulares
II–IV Deep cervical lymph nodes along the vena jugularis interna (lateral jugular lymph nodes):
- **II** Nodi lymphoidei cervicales laterales profundi superiores
- **III** Deep cervical lymph nodes (middle lateral group)
- **IV** Nodi lymphoidei cervicales laterales profundi inferiores

V Lymph nodes in the posterior cervical triangle
VI Nodi lymphoidei cervicales anteriores

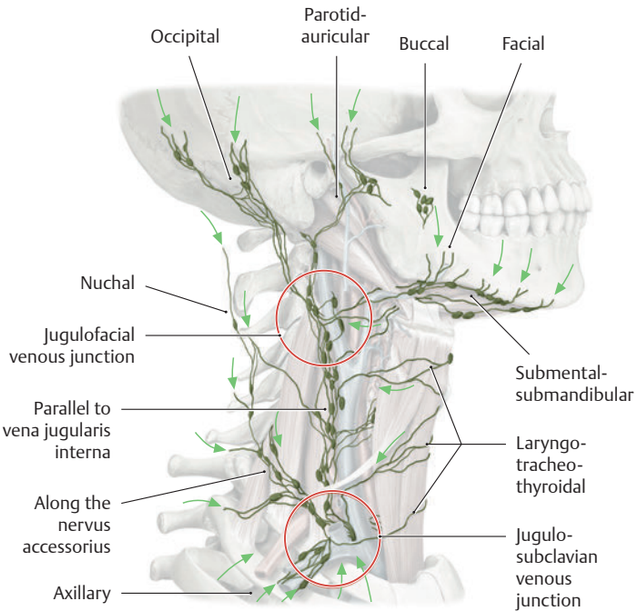


***Fig. 3.27* Directions of lymphatic drainage in the neck**
Right lateral view. Understanding this pattern of lymphatic flow is critical to identifying the location of a potential cause of enlarged nodi lymphoidei cervicales.There are two main sites in the neck where the lymphatic pathways intersect:

- Jugulofacial venous junction: Lymphatics from the head pass obliquely downward to this site, where the lymph is redirected vertically downward in the neck.
- Jugulosubclavian venous junction: The main lymphatic trunk, the ductus thoracicus, terminates at this central location, where lymph collected from the left side of the head and neck region is combined with lymph draining from the rest of the body.

If only peripheral nodal groups are affected, this suggests a localized disease process. If the central groups (e.g., those at the venous junctions) are affected, this usually signifies an extensive disease process. Central lymph nodes can be obtained for diagnostic evaluation by prescalene biopsy.

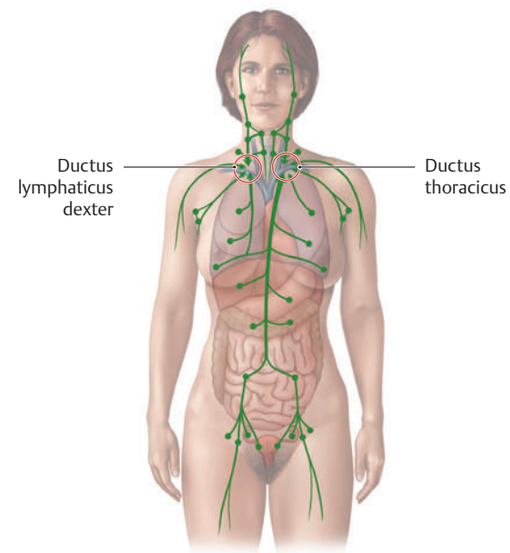


***Fig. 3.28* Relationship of the nodi lymphoidei cervicales to the systemic lymphatic circulation**
Anterior view. The nodi lymphoidei cervicales may be involved by diseases that are not primary to the head and neck region, because lymph from the entire body is channeled to the left and right jugulosubclavian junctions (red circles). This can lead to retrograde involvement of the nodi cervicales. The *ductus lymphaticus dexter* terminates at the right jugulosubclavian junction, the *ductus thoracicus* at the left jugulosubclavian junction. Besides cranial and cervical tributaries, the lymph from nodi lymphoidei thoracis (mediastinal and tracheobronchiales) and from nodi lymphoidei abdominis and caudal lymph nodes may reach the cervical nodes by way of the ductus thoracicus. As a result, diseases in those organs may lead to cervical lymph node enlargement. For example, gastric carcinoma may metastasize to the left nodi lymphoidei supraclaviculares, producing an enlarged *sentinel node* that suggests an abdominal tumor. Systemic lymphomas may also spread to the nodi lymphoidei cervicales by this pathway.

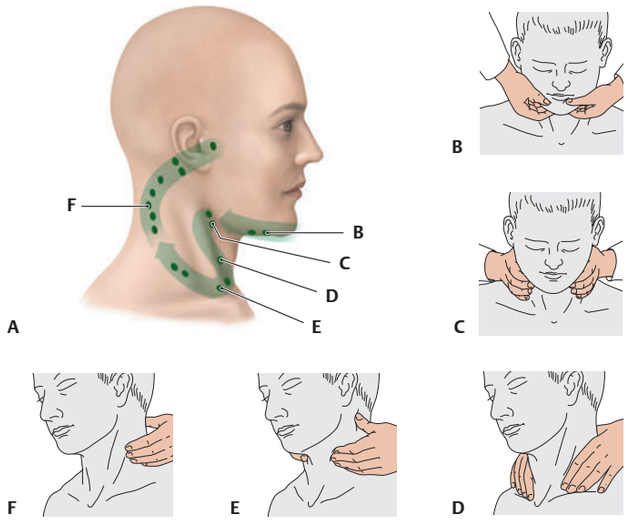


***Fig. 3.29* Systematic palpation of the nodi lymphoidei cervicales**
The nodi lymphoidei cervicales are systematically palpated during the physical examination to ensure the detection of any enlarged nodes.
Panel **A** shows the sequence in which the various nodal groups are successively palpated. The examiner usually palpates the nodi lymphoidei submentales and submandibulares first (**B**), including the angulus mandibulae (**C**), then proceeds along the anterior border of the musculus sternocleidomastoideus (**D**). The nodi lymphoidei supraclaviculares are palpated next (**E**), followed by the nodi lymphoidei accessorii and the nuchal group of nodes (**F**).
If lymph nodes are palpable, the following characteristics should be noted and described: size (<1 cm in diameter is normal), pain/tenderness (suggestive of inflammation), consistency (soft nodes suggest inflammation; firm, rubbery nodes suggest lymphoma; stony-hard nodes may be a sign of cancer), location of lymphadenopathy, and whether it is localized or generalized as this may help aid diagnosis.

Lymphatics of the Head & Neck (II)

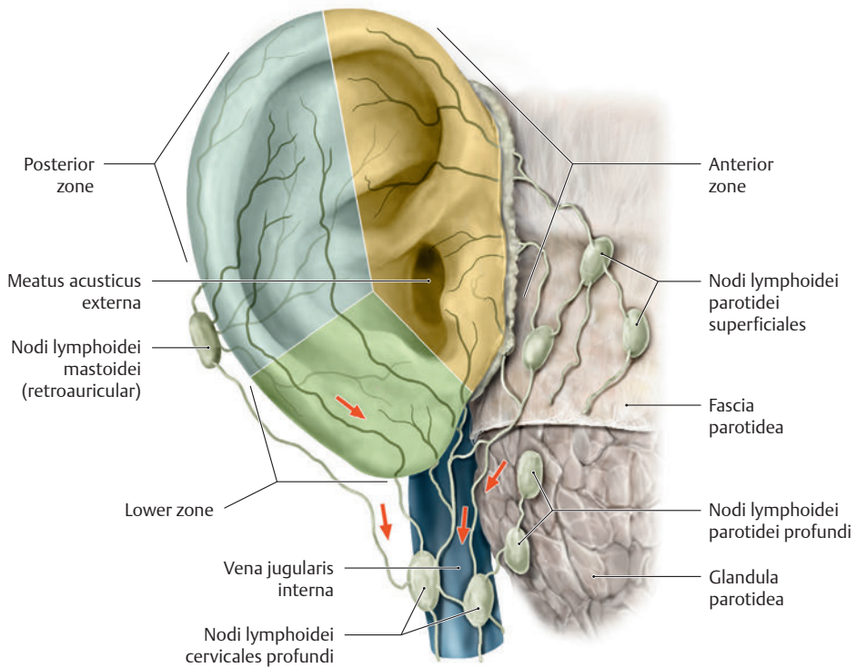


Fig. 3.30 **Auricula and meatus acusticus externus: lymphatic drainage**
Right ear, oblique lateral view. The lymphatic drainage of the ear is divided into three zones, all of which drain directly or indirectly into the nodi lymphoidei cervicales profundi along the vena jugularis interna. The lower zone drains directly into the nodi lymphoidei cervicales profundi. The anterior zone first drains into the nodi lymphoidei parotidei, the posterior zone into the nodi lymphoidei mastoidei.

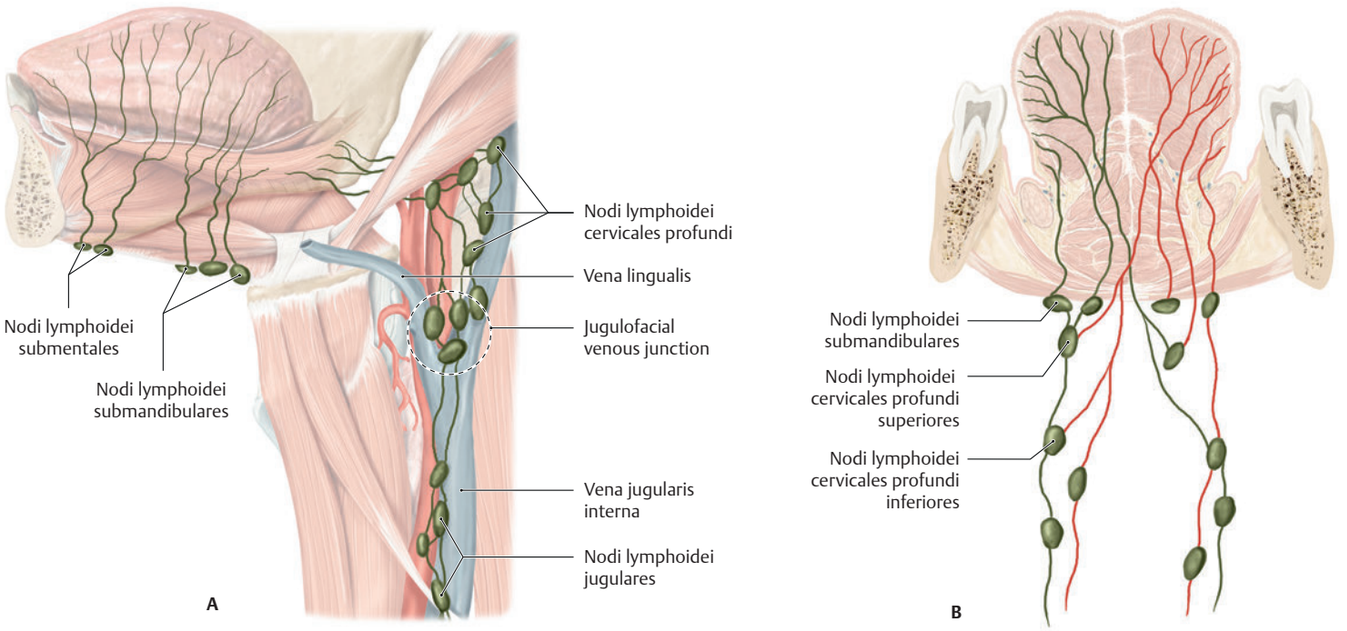


Fig. 3.31 **Lymphatic drainage of the tongue and oral floor**
A Left lateral view. **B** Anterior view.
The lymphatic drainage of the tongue and oral floor is mediated by nodi lymphoidei submentales and submandibulares that ultimately drain into the lymph nodes along the vena jugularis interna (**A**, nodi lymphoidei jugulares). Because the lymph nodes receive drainage from both the ipsilateral and contralateral sides (**B**), tumor cells may become widely disseminated in this region (e.g., metastatic squamous cell carcinoma, especially on the lateral border of the tongue, frequently metastasizes to the opposite side).

Table 3.13 **Lymphatic drainage of the head and neck**

Note: Lymphatic drainage of the cavitas oris is in bold.

Region	Node(s)	Secondary node(s)
Occipital region of the scalp and upper neck	Nodi occipitales	Nodi lymphoidei cervicales superficiales
Scalp in temporoparietal region, posterior surface of the ear, and skin in mastoid region	Nodi lymphoidei mastoidei (retroauricular)	Nodi lymphoidei cervicales superficiales and profundi
Anterior parietal region of the scalp, anterior surface of the ear, meatus acusticus externa, face, and **buccal mucosa**	**Nodi parotidei superficiales (preauricular)**	**Nodi parotidei profundi and cervicales profundi**
Meatus acusticus externa, tuba auditiva, auris media	Nodi parotidei profundi	Nodi cervicales profundi
Cavitas nasi, sinus paranasales, **palatum durum (rarely), palatum molle**, pars nasalis pharyngis, pars oralis pharyngis, and tubae auditivae	**Nodi retropharyngeales**	**Nodi cervicales profundi**
Superficial face and cheek	**Buccal nodes**	**Nodi submandibulares**
labium superius, lateral part of the labium inferius, cheek, vestibulum nasi, anterior cavitas nasi, **gingivae, dentes, medial canthus, palatum durum, palatum molle, anterior pillar, anterior part of the tongue, glandulae submandibulares and sublinguales, and floor of mouth**	**Nodi submandibulares**	**Nodi cervicales profundi**
Chin, middle part of the labium inferius, **anterior gingivae, apex linguae,** and **anterior floor of mouth**	**Nodi submentales**	**Nodi submandibulares and cervicales profundi**
Cavitas oris, pars oralis pharyngis, pars nasalis pharyngis, pars laryngea pharyngis, larynx, and glandula parotidea	**Nodi jugulodigastrici**	**Nodi cervicales profundi**
Submental region, head and neck above this level	Nodi juguloomohyoidei	Nodi cervicales profundi
Oesophagus, larynx, trachea, and glandula thyroidea	Juxtavisceral nodes (nodi prelaryngei, pretracheales, and paratracheales)	Nodi cervicales profundi
Skin and muscles of the anterior infrahyoid region of the neck	Nodi jugulares anteriores	Nodi cervicales profundi
Inferior part of the ear and parotid region	External jugular nodes Nodi tracheales	Nodi cervicales profundi
Lungs, upper oesophagus, part of the larynx below the plicae vocales	Nodi tracheales	Truncus bronchomediastinalis
Lateral part of the neck, anterior thoracic wall, glandula mammaria	Transverse cervical nodes	Truncus jugularis, or ductus lymphaticus dexter, or ductus thoracicus

Most of the lymph from the head and neck ultimately drains to the nodi cervicales superficiales or profundi then into the truncus jugularis. Some lymph also drains into the truncus bronchomediastinalis. These trunks both empty into either the ductus thoracicus or ductus lymphaticus dexter and into the venous system.

Organization of the Nervous System

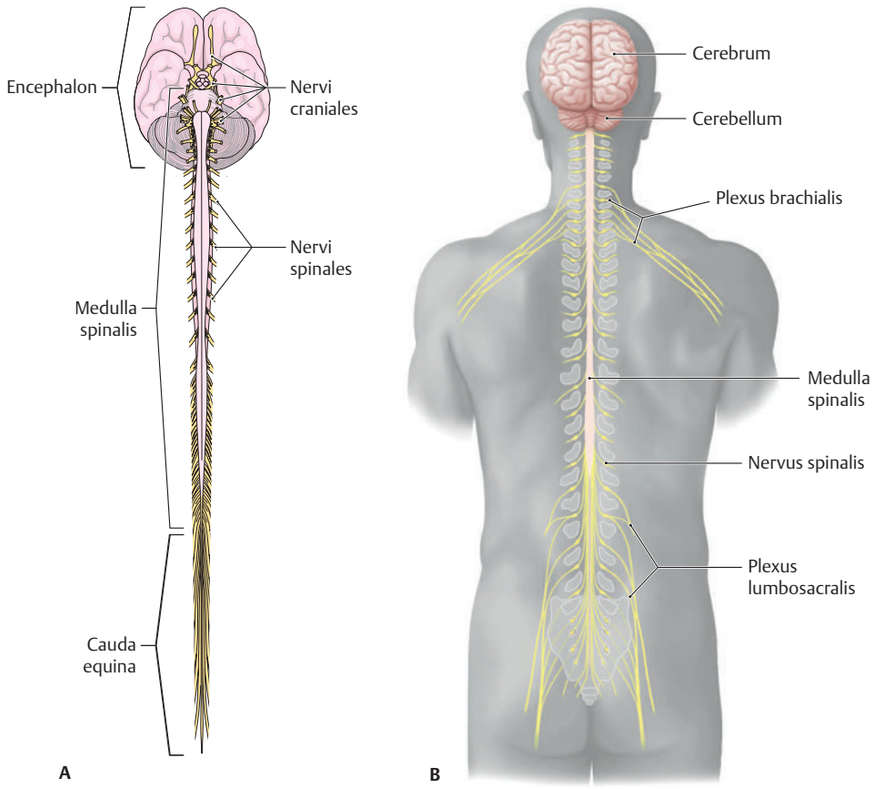


Fig. 4.1 **Nervous system**
A Anterior view. **B** Posterior view. The nervous system is a collection of neurons that can be divided anatomically into two groups:

- **Central nervous system** (CNS, pink): Encephalon and medulla spinalis.
- **Peripheral nervous system** (PNS, yellow): Nerves emerging from the CNS. These are divided into two types depending on their site of emergence:
  - **Nervi craniales:** 12 pairs of nerves emerge from the encephalon (telencephalon, diencephalon, and truncus encephali only). These nerves may contain sensory and/or motor fibers.
  - **Nervi spinales:** 31 pairs of nerves emerge from the medulla spinalis. Nervi spinales contain both sensory and motor fibers that emerge from the medulla spinalis as separate roots and unite to form the mixed nerve. In certain regions, the nervi spinales may combine to form plexuses (e.g., cervicalis, brachialis, or lumbosacralis).

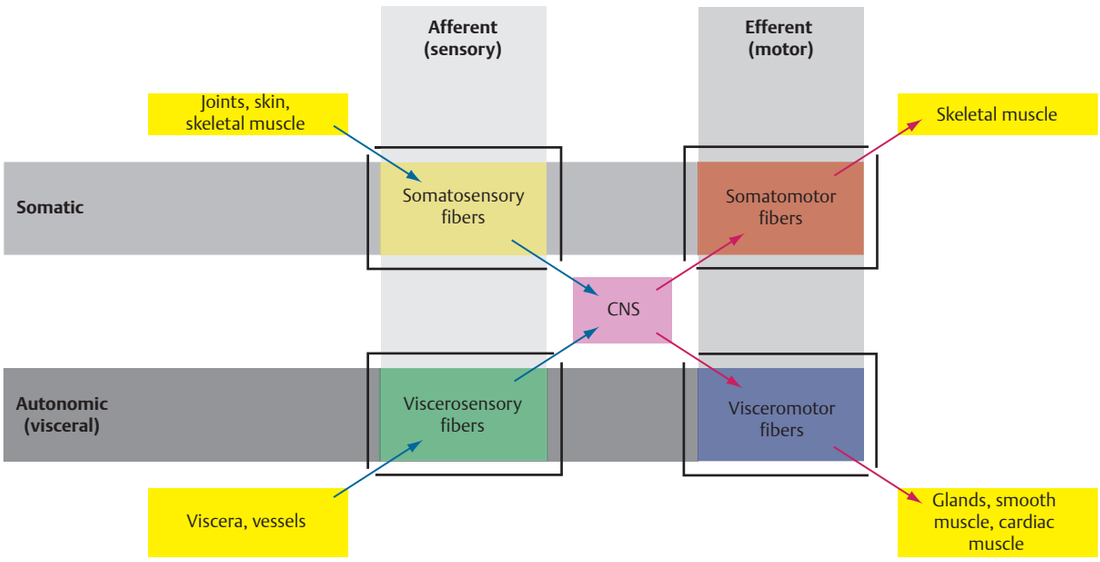


Fig. 4.2 **Organization of the nervous system**
The nervous system is a vast network that can be divided according to two criteria:

1. Type of information: Afferent (sensory) cells and pathways receive information and transmit it to the CNS. Efferent (motor) cells and pathways convey information from the CNS.
2. Destination/origin: The somatic division of the nervous system primarily mediates interaction with the external environment. These processes are often voluntary. The autonomic (visceral) nervous system primarily mediates regulation of the internal environment. These processes are frequently involuntary.

These two criteria yield four types of nerve fibers addressed above that connect the CNS to the PNS.

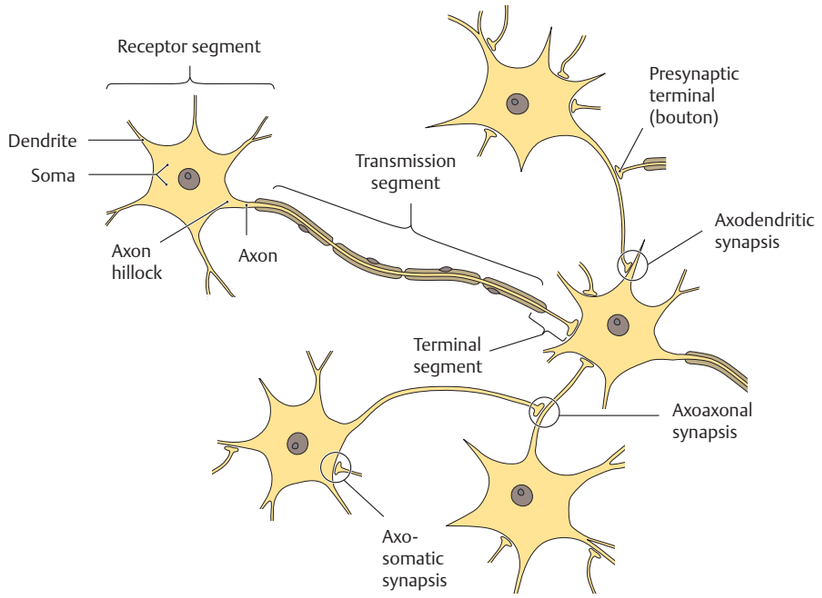


Fig. 4.3 **Neurons (nerve cells)**
The nervous system is composed of neurons (nerve cells) and supporting neuroglial cells, which vastly outnumber them (10 to 1). Each neuron contains a cell body (soma) with one axon (projecting segment) and one or more dendrites (receptor segments). The release of neurotransmitters at synapses creates an excitatory or inhibitory postsynaptic potential at the target neuron. If this exceeds the depolarization threshold of the neuron, the axon "fires," initiating the release of a transmitter from its presynaptic knob (bouton).

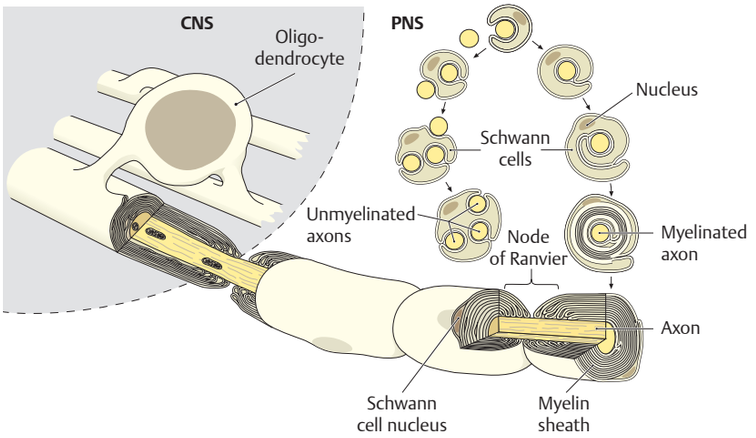


Fig. 4.4 **Myelination**
Certain glial cells with lipid-rich membranes may myelinate axons (nerve fibers). Myelination electrically insulates axons, thereby increasing impulse conduction speed. In the central nervous system, one oligodendrocyte myelinates one internode on multiple axons; in the peripheral nervous system, one Schwann cell myelinates one internode on a single axon.

Table 4.1 **Cells of the central nervous system (CNS) and peripheral nervous system (PNS)**

Cell type	Function
Neurons (CNS and PNS)	Impulse formation, impulse conduction, information processing
Glial cells	
Astrocytes (CNS only)	Maintain a constant internal milieu in the CNS, help form the blood–brain barrier, phagocytosis of non-functioning synapses, scar formation in the CNS (e.g., following cerebral infarction [stroke] or in multiple sclerosis), absorb excess neurotransmitters and K^+
Microglial cells (CNS only)	Cells specialized for phagocytosis and antigen processing; secrete cytokines and growth factors
Oligodendrocytes (CNS only)	Form myelin sheaths in the CNS
Ependymal cells (CNS only)	Line cavities in the CNS
Cells of the plexus choroideus (CNS only)	Secrete liquor cerebrospinalis (CSF)
Schwann cells (PNS only)	Form myelin sheaths in the PNS
Satellite cells (PNS only)	Modified Schwann cells; surround the cell body of neurons in PNS ganglia

Medulla Spinalis: Overview

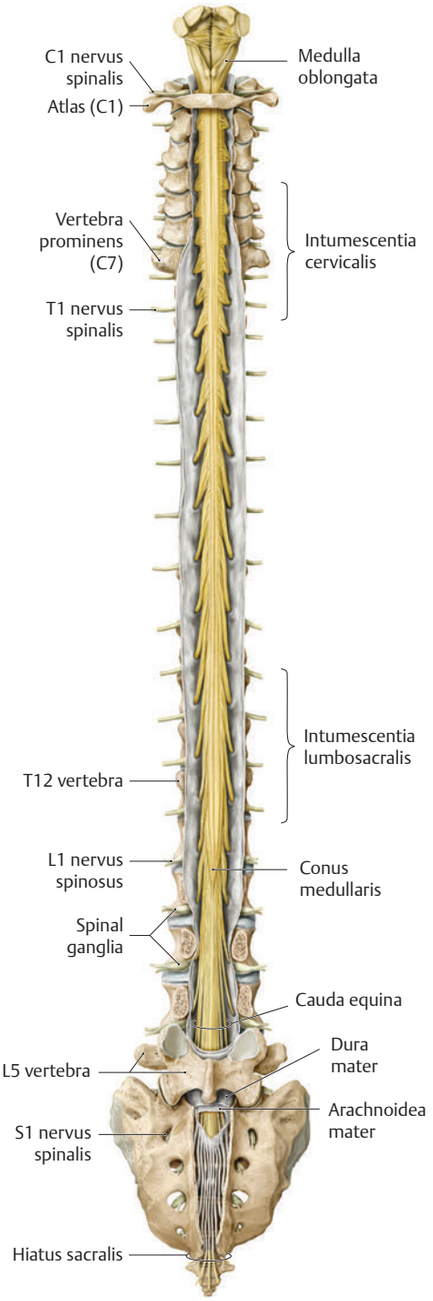


Fig. 4.5 **Medulla spinalis in situ**
Posterior view with canalis vertebralis windowed.
The medulla spinalis is located in the foramen vertebrale and extends from the medulla oblongata to around the level of T12/L1. It gives off 31 pairs of nervi spinales. The *intumescentia cervicalis* corresponds with the attachments of the large nerves that supply the upper limbs. It extends from about C3 to T1. Similarly, the *intumescentia lumbosacralis* corresponds with the attachments of the large nerves that supply the lower limbs. The intumescentia lumbosacralis and anteriores extending from the lower end of the medulla spinalis are collectively known as the cauda equina. During lumbar puncture at this level, a needle introduced into the spatium subarachnoideum (cisterna lumbalis) normally slips past the rami without injuring them (see **Fig. 4.9**).

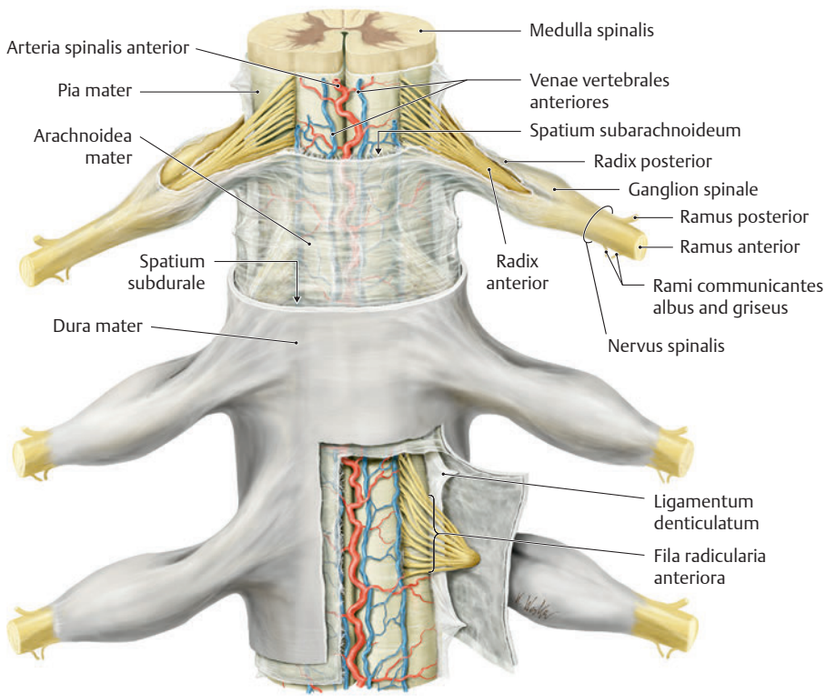


Fig. 4.6 **Medulla spinalis and its meningeal layers**
Posterior view. The dura mater is opened and the arachnoidea mater is sectioned.The medulla spinalis, like the encephalon, is covered by three meninges. The outermost layer, the tough dura mater, extends from the foramen magnum to the os sacrum and coccyx. The middle layer, the arachnoidea mater, loosely envelopes the medulla spinalis and extends from foramen magnum to around the S2 vertebral level. The inner layer, the pia mater, closely invests the medulla spinalis and the arteria spinalis anterior.

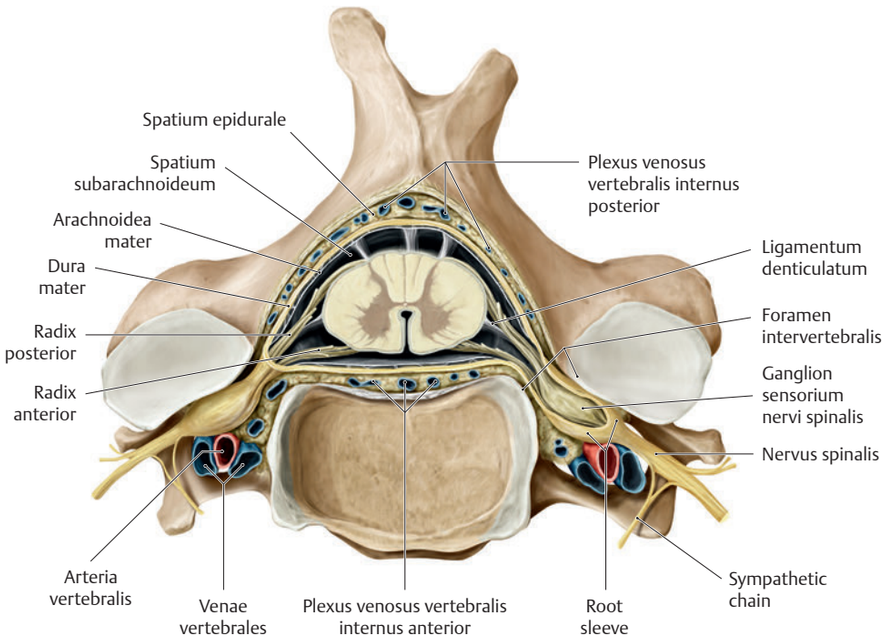


Fig. 4.7 **Medulla spinalis in the canalis vertebralis**
Transverse section at the level of the C4 vertebra, viewed from above. The medulla spinalis occupies the center of the foramen vertebrale and is anchored within the spatium subarachnoideum to the spinal dura mater by the ligamentum denticulatum. The root sleeve, an outpouching of the dura mater in the foramen intervertebrale, contains the ganglion sensorium nervi spinalis and the radices posterior and anterior of the nervus spinalis. The spinal dura mater is bounded externally by the spatium epidurale, which contains venous plexuses, fat, and connective tissue. The spatium epidurale extends upward as far as the foramen magnum, where the dura becomes fused to the cranial periosteum.

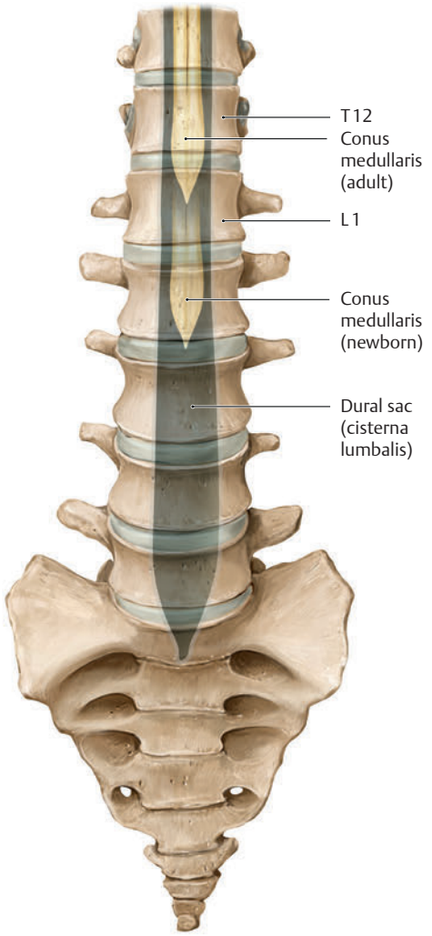


Fig. 4.8 **Age-related changes of spinal cord levels**
Anterior view. As an individual grows, the longitudinal growth of the medulla spinalis increasingly lags behind that of the columna vertebralis. At birth the distal end of the medulla spinalis, the conus medullaris, is at the level of the L3 vertebral body (where lumbar puncture is contraindicated). The medulla spinalis of a tall adult ends at the T12/L1 level, whereas that of a short adult extends to the L2/L3 level. The dural sac always extends into the upper sacrum. It is important to consider these anatomical relationships during lumbar puncture. It is best to introduce the needle at the L3/L4 interspace (see **Fig. 4.9**).

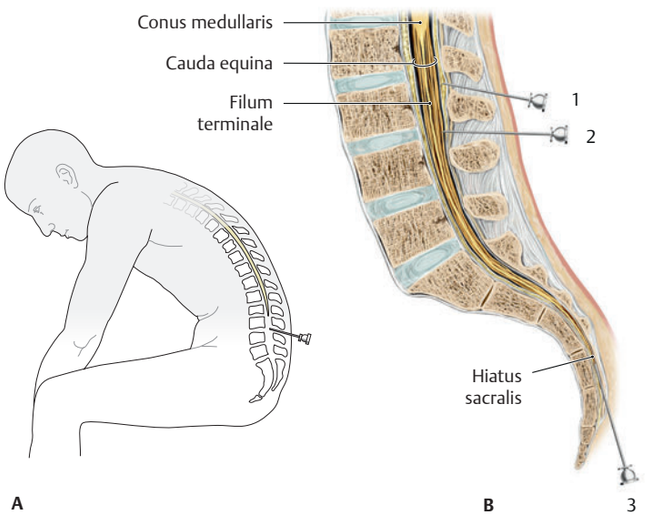


Fig. 4.9 **Lumbar puncture, epidural anesthesia, and lumbar anesthesia**
In preparation for a **lumbar puncture**, the patient bends far forward to separate the processi spinosi of the lumbar spine. The spinal needle is usually introduced between the processi spinosi of the L3 and L4 vertebrae. It is advanced through the skin and into the dural sac (cisterna lumbalis, see **Fig. 4.8**) to obtain a CSF sample. This procedure has numerous applications, including the diagnosis of meningitis. For **epidural anesthesia**, a catheter is placed in the spatium epidurale without penetrating the dural sac (1). **Lumbar anesthesia** is induced by injecting a local anesthetic solution into the dural sac (2). Another option is to pass the needle into the spatium epidurale through the hiatus sacralis (3).

Medulla Spinalis: Circuitry & Nervi Spinales

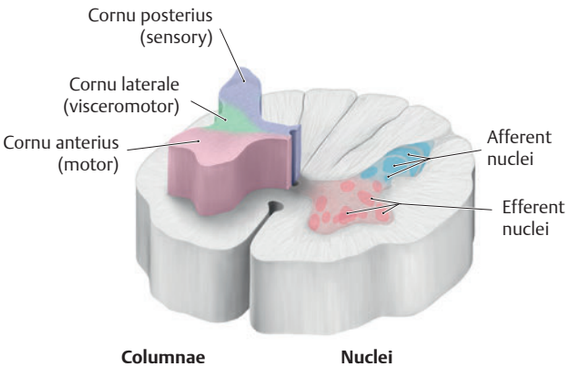


Fig. 4.10 **Organization of the substantia grisea**
Left oblique anterosuperior view. The substantia grisea of the medulla spinalis is divided into three columnae (cornua). Afferent (blue) and efferent (red) neurons within these columnae are clustered according to function.

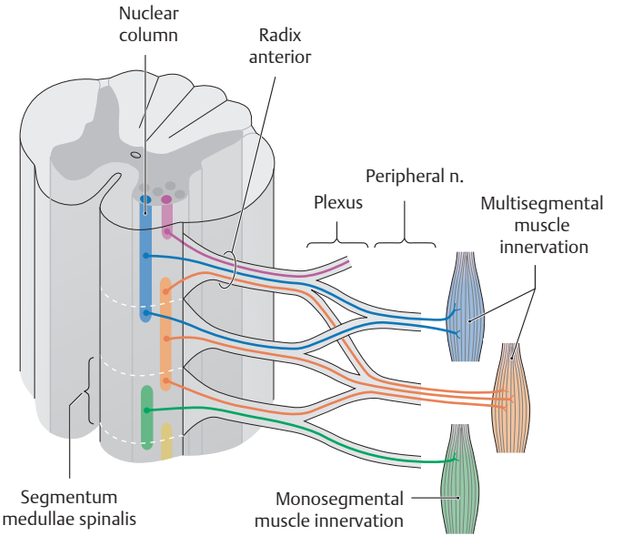


Fig. 4.11 **Muscle innervation**
Indicator muscles are innervated by motor neurons in the cornu anterius of one segmentum medullae spinalis. Most muscles (multisegmental muscles) receive innervation from a motor column, a vertical arrangement of motor nuclei spanning several segments.

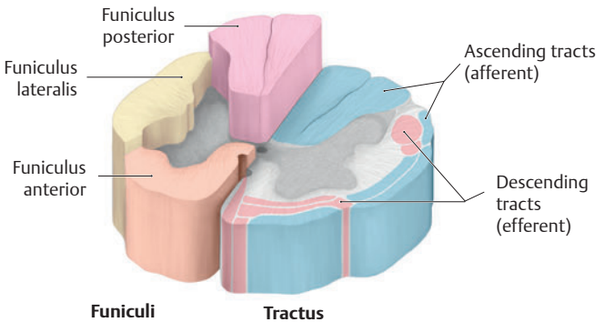


Fig. 4.12 **Reflexes**
Principal intrinsic fascicles of the medulla spinalis. Muscular function at the unconscious (reflex) level is controlled by the substantia grisea of the medulla spinalis. The intrinsic fascicles are the conduction apparatus of the intrinsic circuits, allowing axons to ascend and descend to coordinate spinal reflexes for multisegmental muscles.

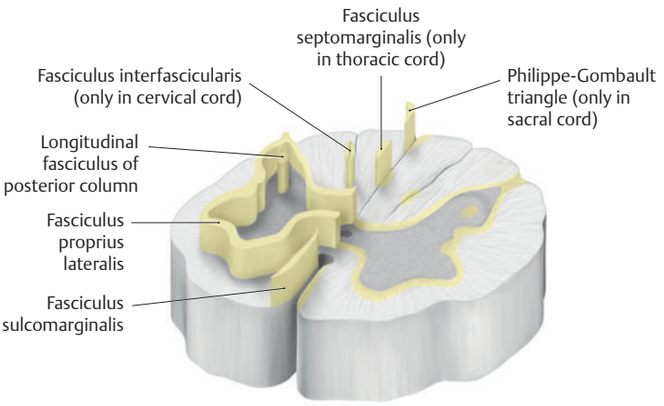


Fig. 4.13 **Sensory and motor systems**
Substantia alba of the medulla spinalis. The substantia alba of the medulla spinalis contains ascending tracts (afferent tracts) and descending tracts (efferent tracts), which are the CNS equivalent of peripheral nerves. The sensory system (see pp. 104, 105 and motor system (see pp. 108, 109) are so functionally interrelated they may be described as one (sensorimotor system).

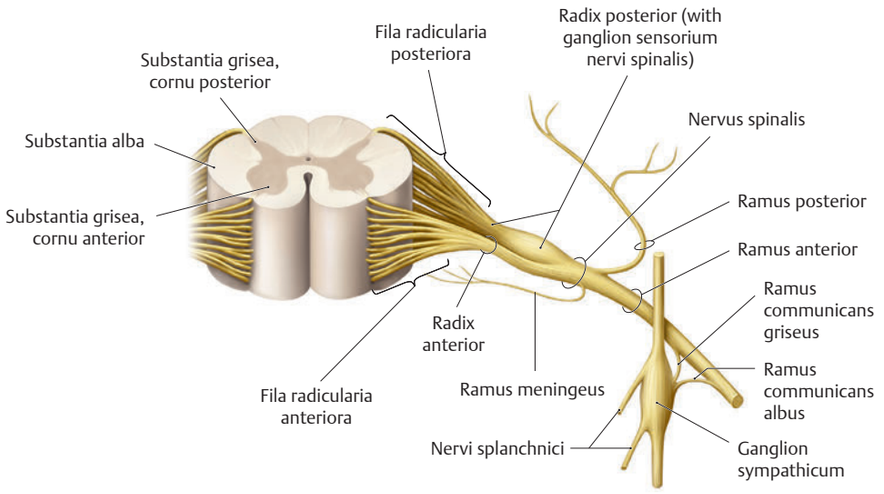


Fig. 4.14 **Segmentum medullae spinalis**
The medulla spinalis consists of 31 segmenta, each innervating a specific area of the skin (a dermatome) of the head, trunk, or limbs. Afferent (sensory) fila radicularia posteriora and efferent (motor) fila radicularia anteriora form the radices posterior and anterior of the nervus spinalis for that segmentum. The two roots fuse to form a mixed (motor and sensory) nervus spinalis that exits the foramen intervertebrale and immediately thereafter divides into rami anterior and posterior (or branches).

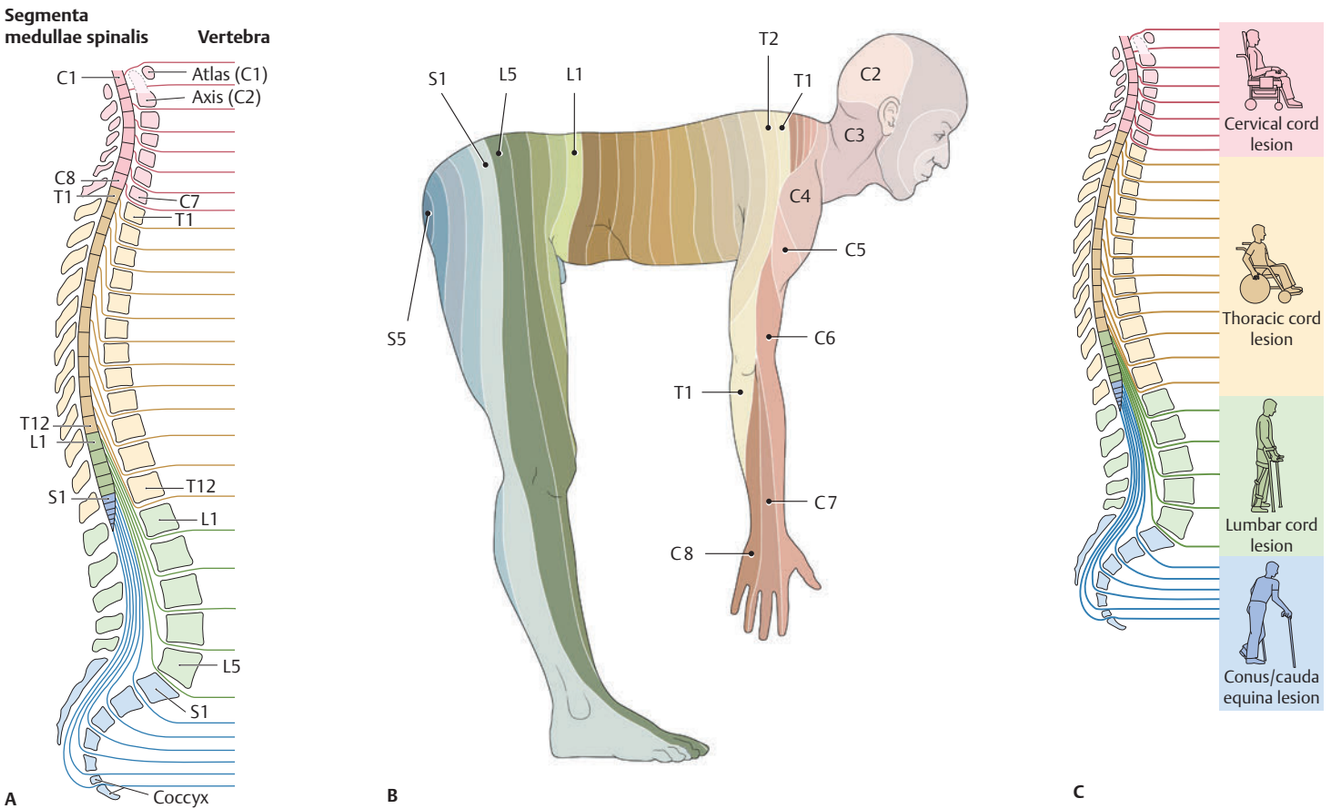


Fig. 4.15 **Segmenta medullae spinalis, dermatomes, and effects of medulla spinalis lesions**
The medulla spinalis is divided into four major regions: cervical, thoracic, lumbar, and sacral. The regions of the medulla spinalis are designated by colors: red, cervical; brown, thoracic; green, lumbar; blue, sacral.

A Segmenta medullae spinalis. Initially nervi spinales pass out above the vertebrae for which they are numbered. However, since there is an 8th cervical nervus spinalis but no 8th cervical vertebra, C8 passes out above the vertebral level T1, and the nervi spinales for T1 and following pass out below the vertebral level for which they are named.

B Dermatome, bandlike areas of skin receiving sensory innervation from a single pair of nervi spinales (from a single segmentum medullae spinalis). *Note:* Nervus spinalis C1 is purely motor; consequently there is no C1 dermatome.

C Effects of lesions in each region of the medulla spinalis.

Organization of the Encephalon & Cerebellum

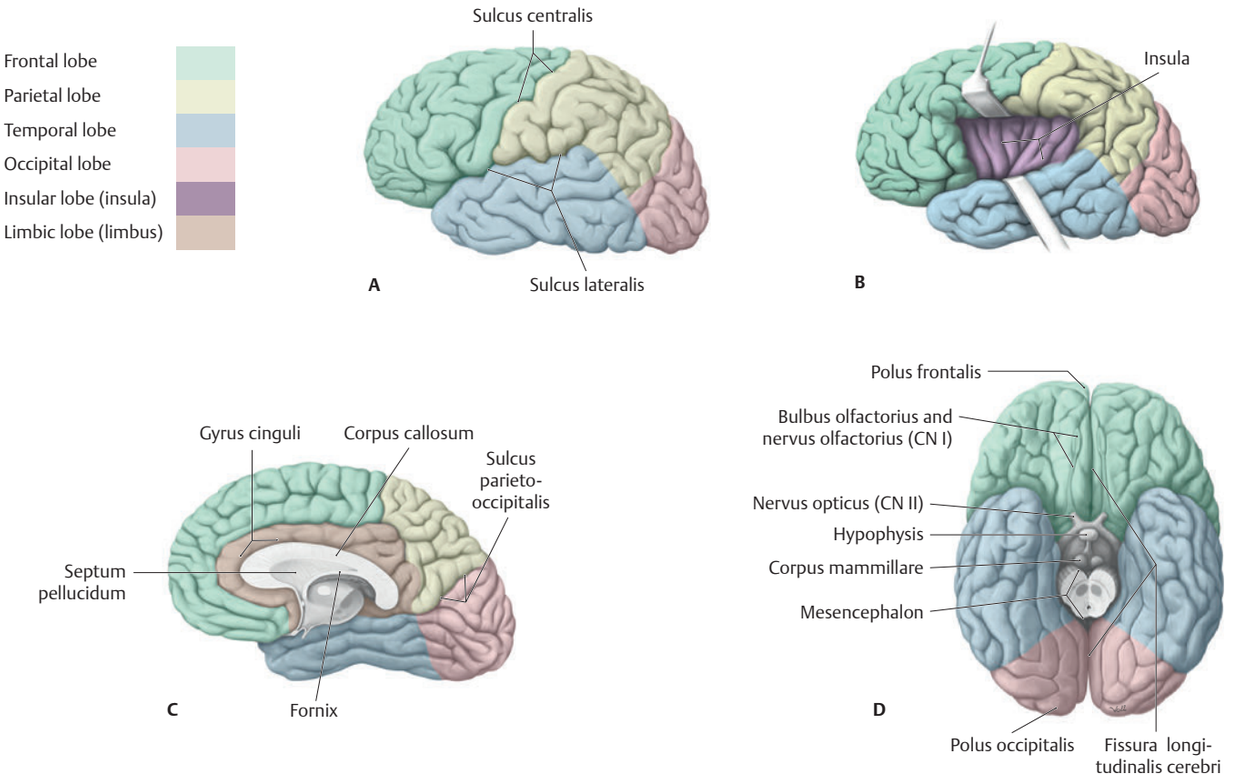


Fig. 4.16 **The encephalon**
A Lateral view of the left hemispherium. **B** Lateral view of the retracted left hemispherium. **C** Lateral view of a sagittal section of the right hemisphere. **D** Basal (inferior) view with the brainstem removed.
The brain is divided in four major parts: telencephalon (cerebrum), diencephalon, truncus encephali, and cerebellum. The telencephalon (cerebrum) is the large outer portion of the encephalon, consisting of two hemispheria separated by a fissura longitudinalis cerebri (see **D**). The telencephalon is divided into five lobi: frontalis, parietalis, temporalis, occipitalis, and insularis (insula). The surface contours of the cerebrum are defined by convolutions (gyri) and depressions (sulci). The sulcus centralis, an important reference point on the cerebrum, separates the gyrus precentralis from the gyrus precentralis (on the lobus frontalis). The gyrus postcentralis (on the lobus parietalis) mediates voluntary motor activity, and the gyrus postcentralis mediates the conscious perception of body sensation. Sulci may be narrowed and compressed in brain edema, due to excessive fluid accumulation in the brain, and are enlarged in brain atrophy (e.g., Alzheimer disease), due to tissue loss from the gyri.

Table 4.2 **Functions of the cerebrum (telencephalon)**

Brain structure	Lobe	Function
Cerebrum (telencephalon)	Lobus frontalis	Motor movement; motor aspect of speech (Broca's area); reasoning; personality; problem solving
	Lobus parietalis	Sensory perceptions related to pain, temperature, touch, and pressure; spatial orientation and perception; sensory aspect of language (Wernicke's area)
	Lobus temporalis	Auditory perceptions; learning; memory
	Lobus occipitalis	Vision
	Insula	Associated with visceral functions, e.g., taste

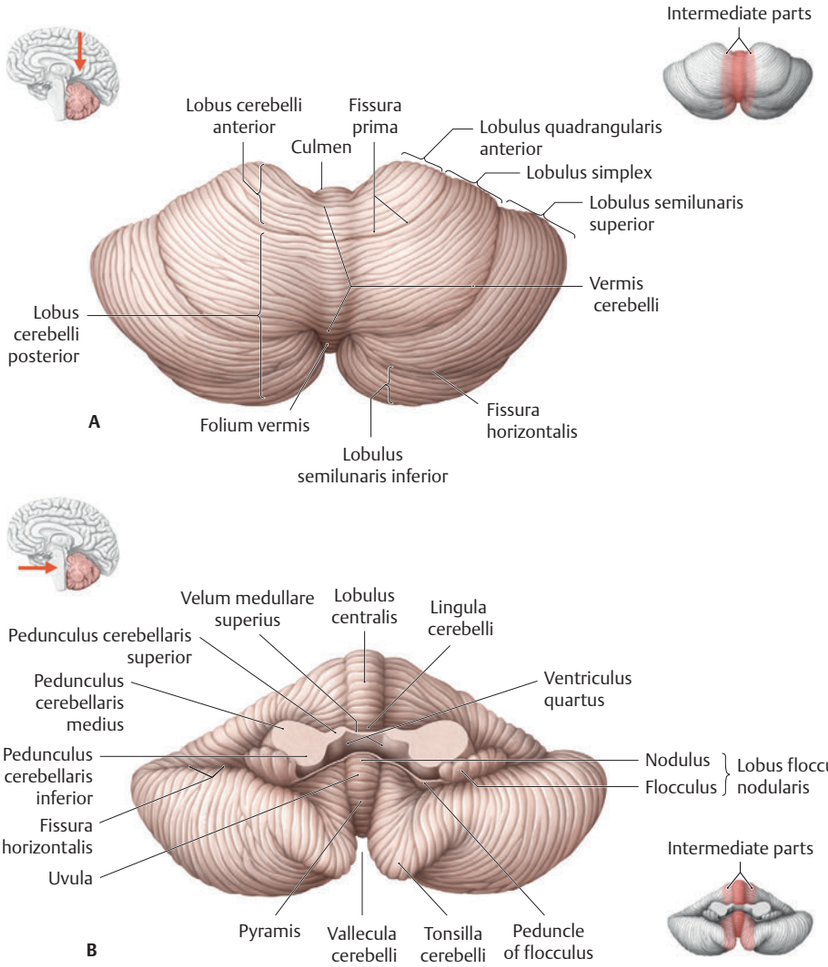


***Fig. 4.17* Cerebellum**
A Superior view. **B** Anterior view.
The cerebellum is part of the motor system. It cannot initiate conscious movements by itself but is responsible for unconscious coordination and fine control of muscle actions. Grossly, the cerebellar surface presents a much finer arrangement of gyri and sulci than the cerebrum, providing an even greater expansion of its surface area. Externally the cerebellum consists of two large lateral masses, the hemispheria cerebelli, and a central part, called the vermis cerebelli. Fissurae cerebelli further subdivide the cerebellum into lobes:

- The fissura prima separates the lobus cerebelli anterior from the lobus cerebelli posterior.
- The fissura posterolateralis separates the lobus cerebelli posterior from the lobus flocculonodularis.

The cerebellum is connected to the truncus encephali by three pedunculi cerebellares (superior, medius, and inferior), through which the afferent and efferent tracts enter and leave the cerebellum (see **Fig 4.18**). The velum medullare superius stretches between the pedunculi cerebellares superiores and forms part of the roof of the ventriculus quartus. The tonsillae cerebelli protrude downward near the midline on each side, almost to the foramen magnum at the base of the skull (not shown). Increased intracranial pressure may cause the tonsillae cerebelli to herniate into the foramen magnum, impinging on vital centers in the truncus encephali and posing a threat to life.

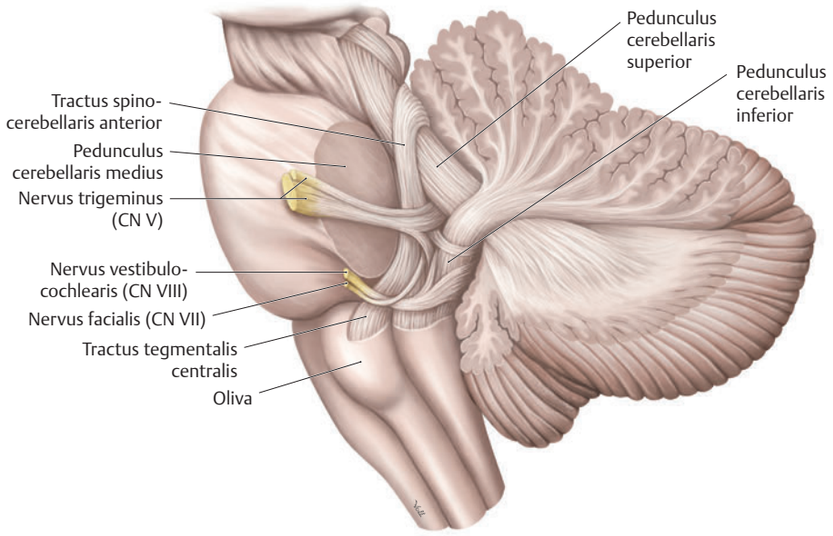


***Fig. 4.18* Pedunculi cerebellares**
Left lateral view. The substantial mass of the pedunculi reflects the extensive neural connections they carry. The cerebellum requires these numerous connections because it is the integrating center for the control of fine movements. It contains and processes vestibular and proprioceptive afferents and modulates motor nuclei in other brain regions and in the medulla spinalis.

Telencephalon (I): Overview, Nuclei Basales, & Neocortex

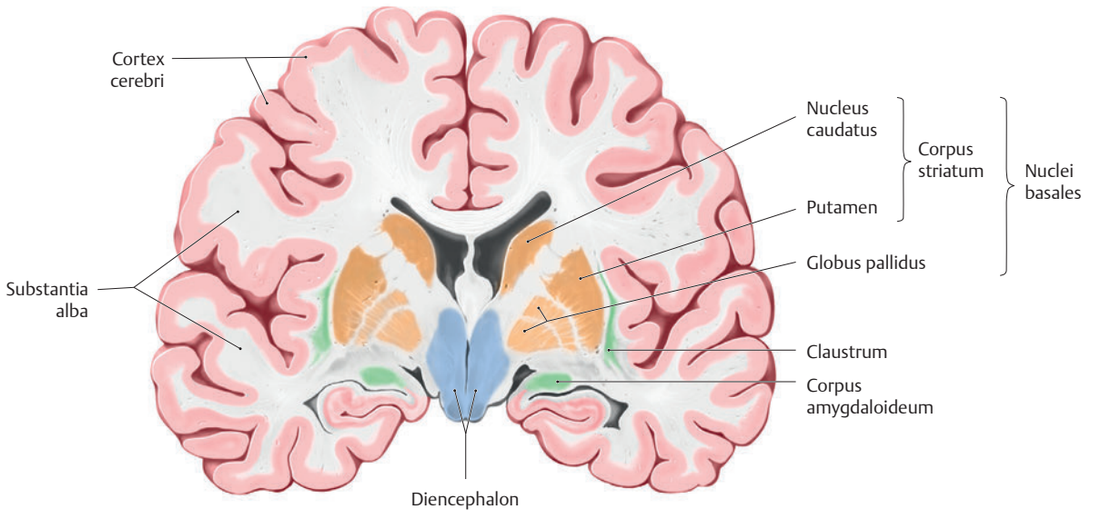


Fig. 4.19 **Divisions of the telencephalon**
Coronal section, anterior view. The telencephalon is divided into the cortex cerebri, substantia alba, and nuclei basales. The cortex cerebri is further divided into the allocortex and neocortex. The allocortex consists of the olfactory cortex and hippocampus. The neocortex is remainder and the largest portion of the cortex cerebri.

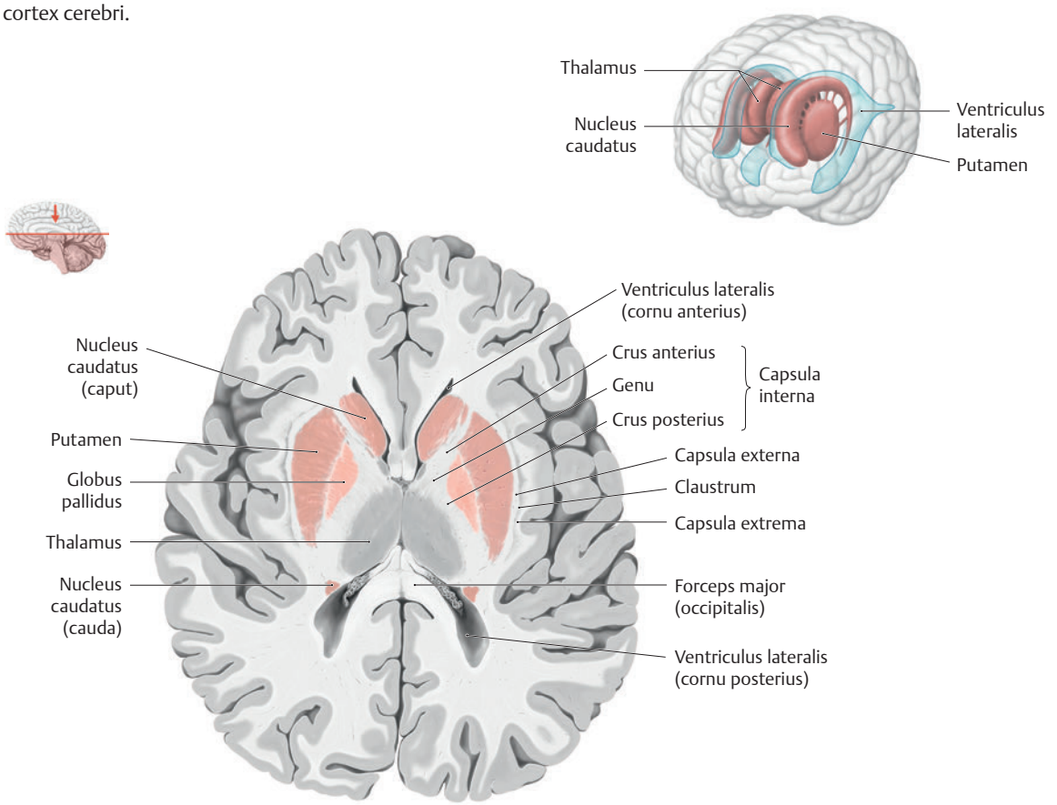


Fig. 4.20 **Nuclei basales**
Transverse section through the cerebrum at the level of the corpus striatum, superior view. The nuclei basales consist of the nucleus caudatus, putamen, and globus pallidus and are an essential component of the extrapyramidal motor system, which controls involuntary movement and reflexes and coordinates complex movements (see p.108). The nucleus caudatus and putamen, which are separated from each other by the fibrous substantia alba of the capsula interna, together constitute the corpus striatum. Deficiency of dopamine in the nuclei basales is responsible for Parkinson disease.

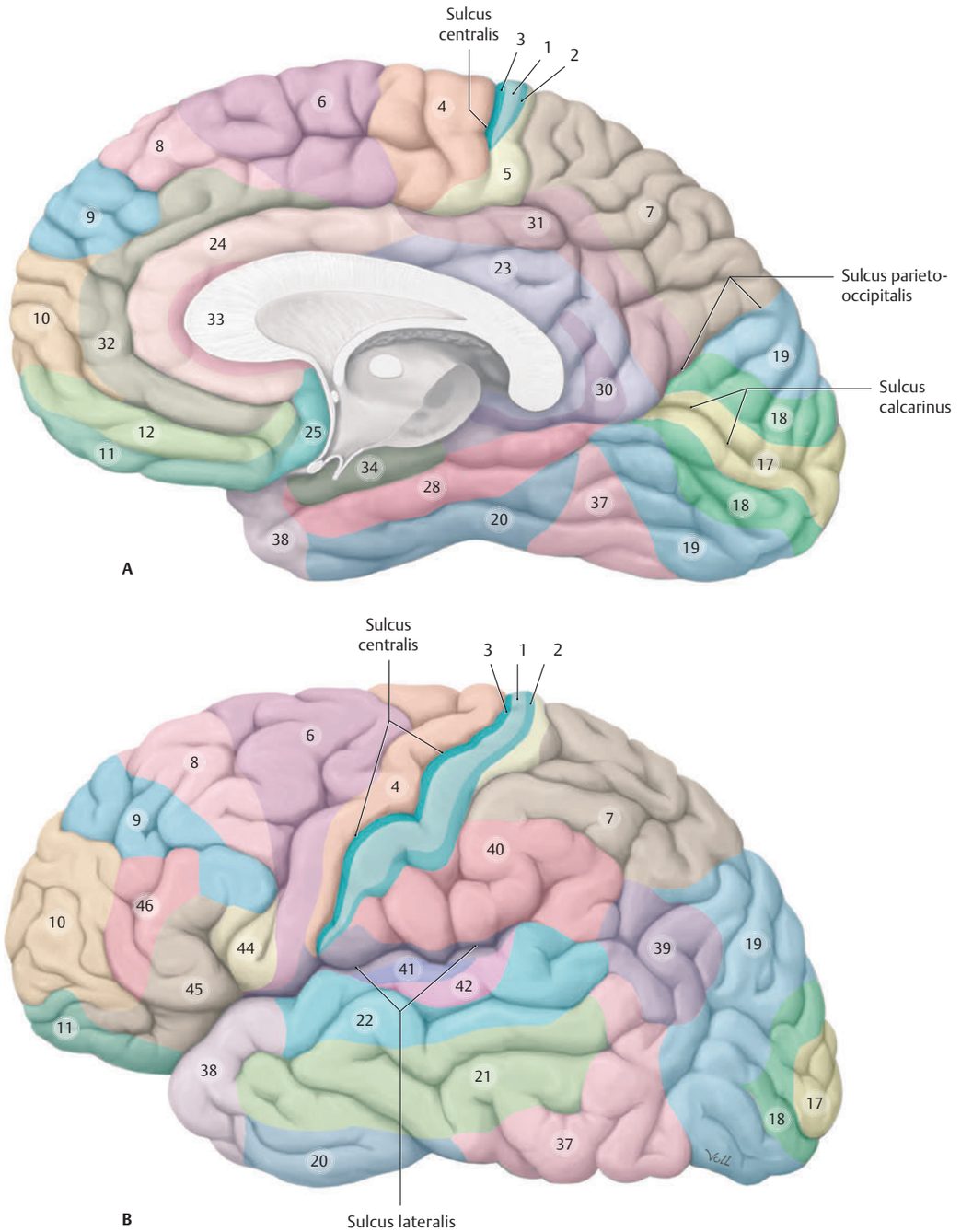


Fig. 4.21 **Brodmann areas in the neocortex**
A Medial view of midsagittal section of the right hemispherium cerebri; **B** Lateral view of the left hemispherium cerebri.
The surface of the encephalon consists macroscopically of lobi, gyri, and sulci. Microscopically, however, subtle differences can be found in the distribution of the cortical neurons, and some of these differences do not conform to the gross surface anatomy of the encephalon. Portions of the cortex cerebri that have the same basic microscopic features are called *cortical areas or cortical fields*. This organization into cortical areas is based on the distribution of neurons in the different layers of the cortex (*cytoarchitectonics*). In the brain map shown above, these areas are indicated by different colors. Although the size of the cortical areas may vary between individuals, the brain map pictured here is still used today as a standard reference chart. It has long been thought that the map (created by Korbinian Brodmann) accurately reflects the functional organization of the cortex, and indeed, modern imaging techniques have shown that many of the cytologically defined areas are associated with specific functions. There is no need, of course, to memorize the location of all the cortical areas, but the following areas are of special interest:

- Areas 1, 2, and 3: primary somatosensory cortex
- Area 4: primary motor cortex
- Area 17: primary visual cortex (striate area, the extent of which is best appreciated in the midsagittal section)
- Areas 41 and 42: auditory cortex

Telecephalon (II): Allocortex & Limbic System

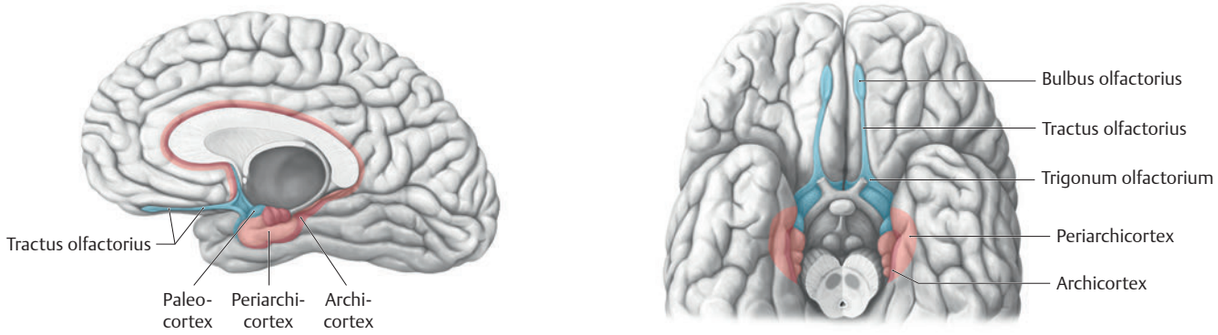


Fig. 4.22 **Allocortex**
A Left lateral view of the right hemispherium. **B** Basal (inferior) view. The allocortex consists of the olfactory cortex (blue) and the hippocampus (pink). The olfactory cortex is involved with processing the sense of smell. It receives sensory afferent impulses directly from the bulbus olfactorius, unlike all other sensory afferent impulses that reach the cortex cerebri via the dorsal thalamus. The hippocampus is an important area for information integration and memory. Damage to the hippocampus, which occurs early in Alzheimer disease, contributes to memory loss and disorientation.

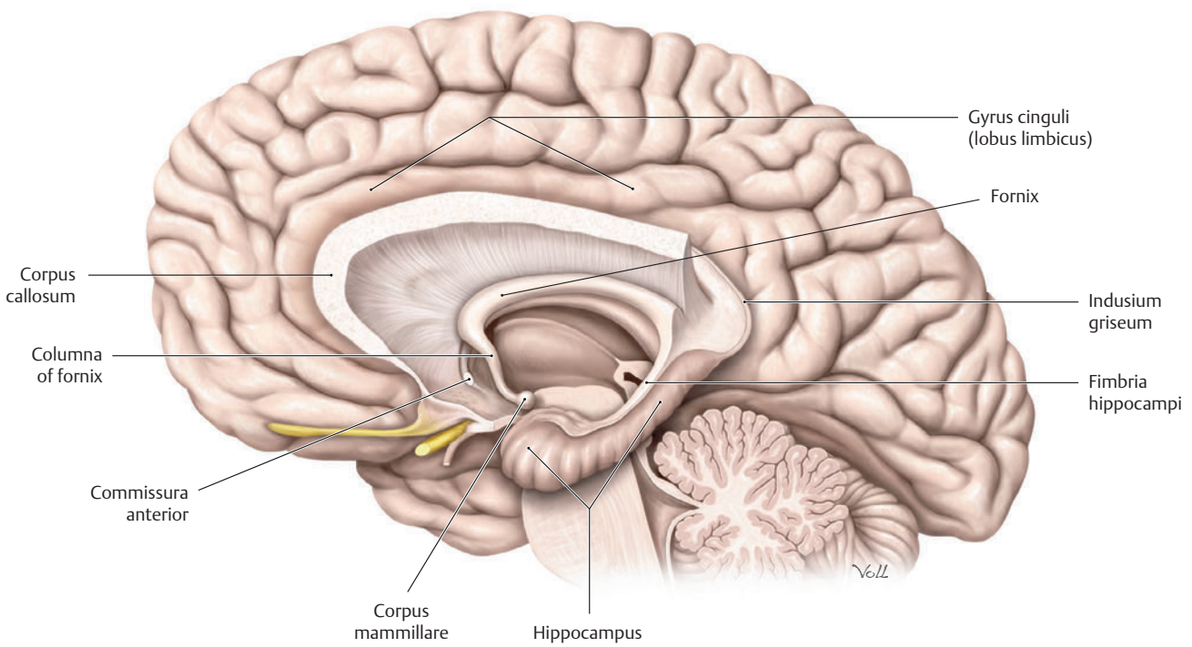


Fig. 4.23 **Left hippocampal formation**
Lateral view. Most of the left hemispherium has been dissected away, leaving only the corpus callosum, fornix, and hippocampus. The intact right hemispherium is visible in the background.
The hippocampal formation is an important component of the *limbic system* (see **Fig. 4.24**). It consists of three parts:

- subiculum (not shown),
- hippocampus proprius, and
- gyrus dentatus (not shown).

The fiber tract of the fornix connects the hippocampus to the corpus mammillare. The hippocampus integrates information from various brain areas and influences endocrine, visceral, and emotional processes via its efferent output. It is particulary associated with the establishment of short-term memory. Lesions of the hippocampus can therefore cause specific deficits in memory formation.

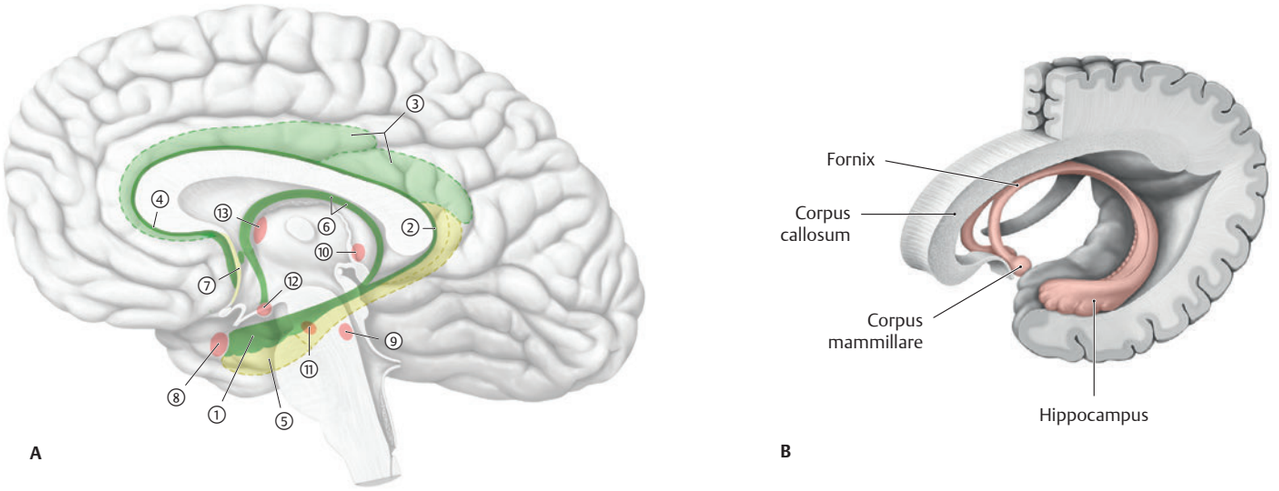


Fig. 4.24 **Limbic system**
A Midsagittal section, left lateral view. B Hippocampus, left anterior oblique view.
The limbic system, which exchanges and integrates information between the telencephalon, diencephalon, and mesencephalon, regulates drive and affective behavior. It plays a crucial role in memory and learning. The corpus amygdaloideum (⑧, one of the subcortical nuclei) is an important structure for the processing of emotions. It is involved in the flight-or-fight response and in sexual pleasure. Dysfunction of the corpus amygdaloideum has been linked to conditions such as anxiety, depression, post-traumatic stress disorder, and phobias.

Table 4.3 **Structures of the limbic system**

Outer arc		Inner arc*		Subcortical nuclei	
①	Gyrus parahippocampalis	⑤	Hippocampal formation (hippocampus, entorhinal area of gyrus parahippocampalis)	⑧	Corpus amygdaloideum
②	Indusium griseum	⑥	Fornix	⑨	Nuclei tegmentales posteriores
③	Area subcallosa (paraolfactoria)	⑦	Septal area (septum)	⑩	Nuclei habenulares
				⑪	Nuclei interpedunculares
④	Gyrus cinguli	Gyrus paraterminalis		⑫	Corpora mammillaria
				⑬	Nuclei anteriores thalami

* The inner arc also contains the diagonal band of Broca (not shown).

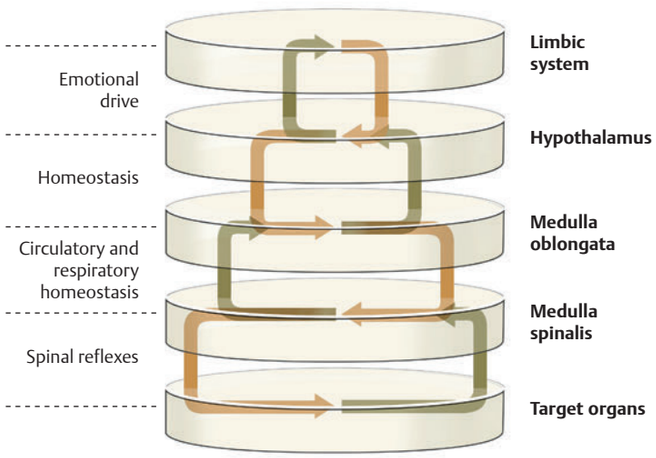


Fig. 4.25 **Limbic regulation of the peripheral autonomic nervous system**
The limbic system receives afferent feedback signals from its target organs. See **Fig 4.68** for a diagram of the autonomic nervous system.

Diencephalon: Overview & Development

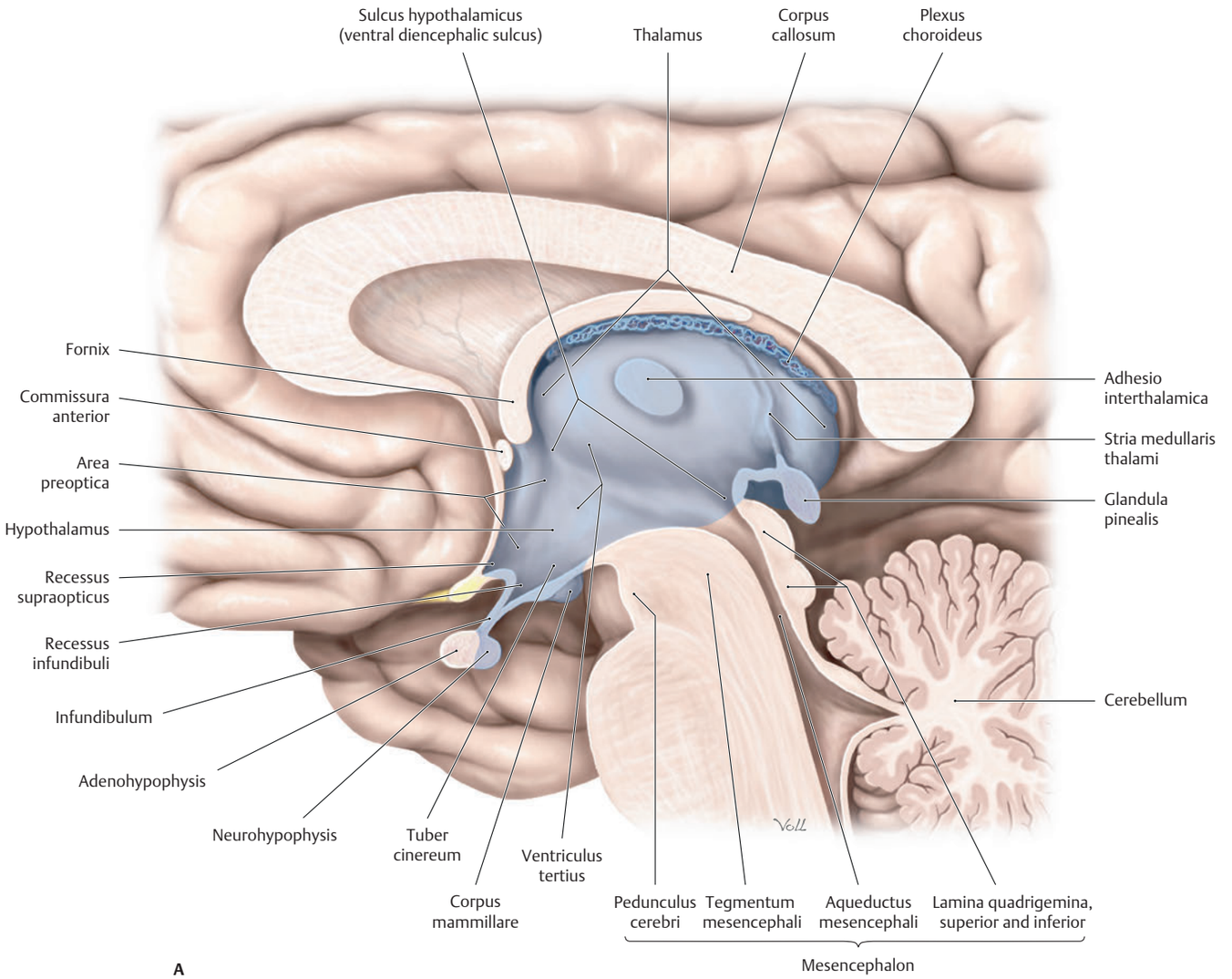


Fig. 4.26 **The diencephalon**

A Diencephalon and truncus encephali in situ, midsagittal section of the right hemispherium viewed from the left side.

B Left lateral view with telencephalon removed. The diencephalon is located below the corpus callosum, part of the telencephalon, and above the mesencephalon (midbrain). The lateral wall of the ventriculus tertius, visible here, forms the medial boundary of the diencephalon. The thalamus makes up four fifths of the entire diencephalon, but the only parts of the diencephalon that can be seen externally are the hypothalamus (visible from the basal aspect) and portions of the epithalamus (glandula pinealis, visible from the occipital aspect). The diencephalon is involved in endocrine functioning and autonomic coordination of the glandula pinealis, the lobus posterior glandulae pituitariae (neurohypophysis), and the hypothalamus. It also acts as a relay station for sensory information and somatic motor control (via the thalamus).

Visible in **B** are the thalamus, the corpus geniculatum laterale, and the tractus opticus. The corpus geniculatum laterale and tractus opticus are components of the visual pathway. *Note:* The retina and associated nervus opticus form an anterior extension of the diencephalon and therefore are colored blue here, which departs from the convention of yellow for nerves.

The tractus opticus marks the lateral boundary of the diencephalon. It winds around the pedunculi cerebrales, which are part of the adjacent mesencephalon (midbrain).

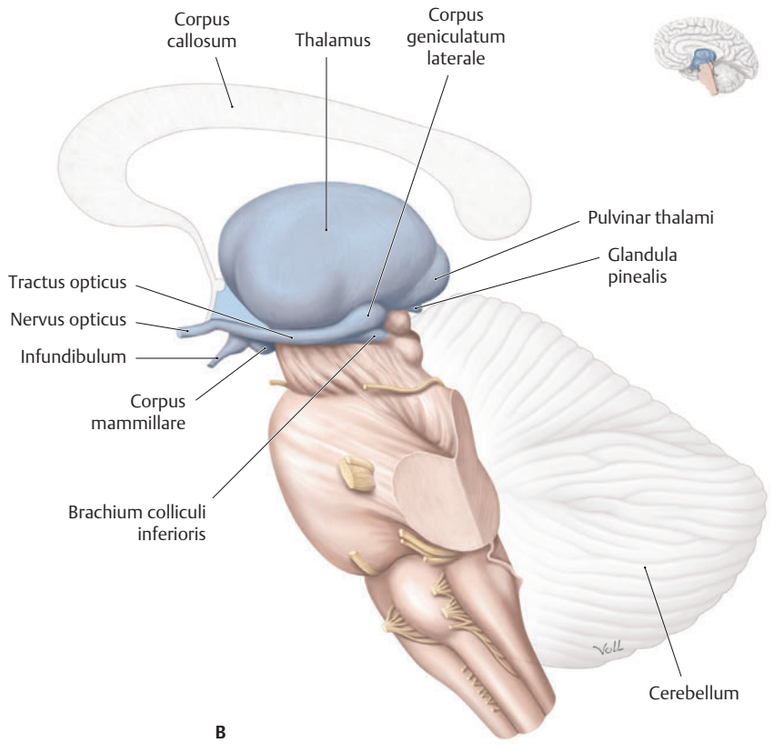


Table 4.4 **Functions of the diencephalon**

Part	Structures	Function
Epithalamus	Glandula pinealis Habenulae	Regulation of circadian rhythms; linking of olfactory system to brain
Thalamus	Thalamus	Relay center for the somatosensory system and parts of the motor system
Subthalamus	Nucleus subthalamicus Zona incerta (not shown) Globus pallidus	Relay of sensory information (somatomotor zone of diencephalon)
Hypothalamus	Chiasma opticum, tractus opticus Tuber cinereum (not shown) Lobus posterior glandulae pituitariae (neurohypophsis) Corpora mammillaria	Coordination of autonomic nervous system with endocrine system; participation in visual pathway

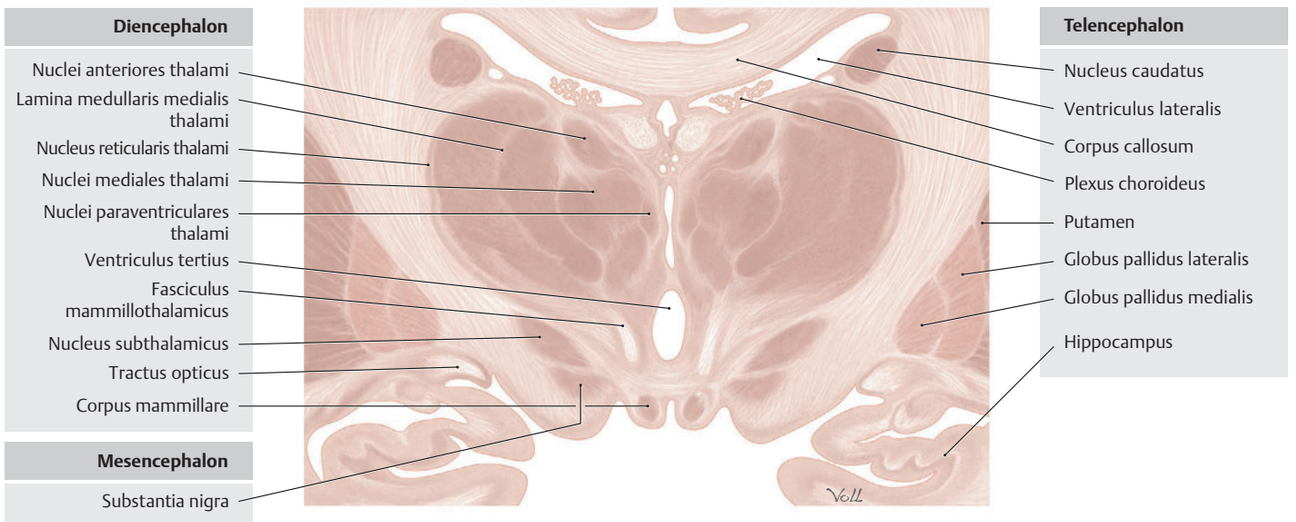
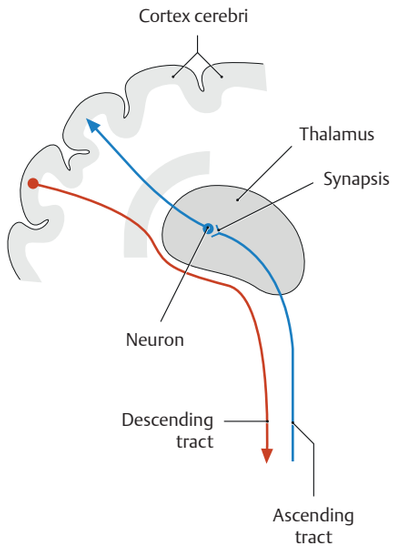


Fig. 4.27 **Internal structure of the diencephalon and telecephalon**
Coronal section at the level of the corpora mammillaria.

Diencephalon: Thalamus & Hypothalamus



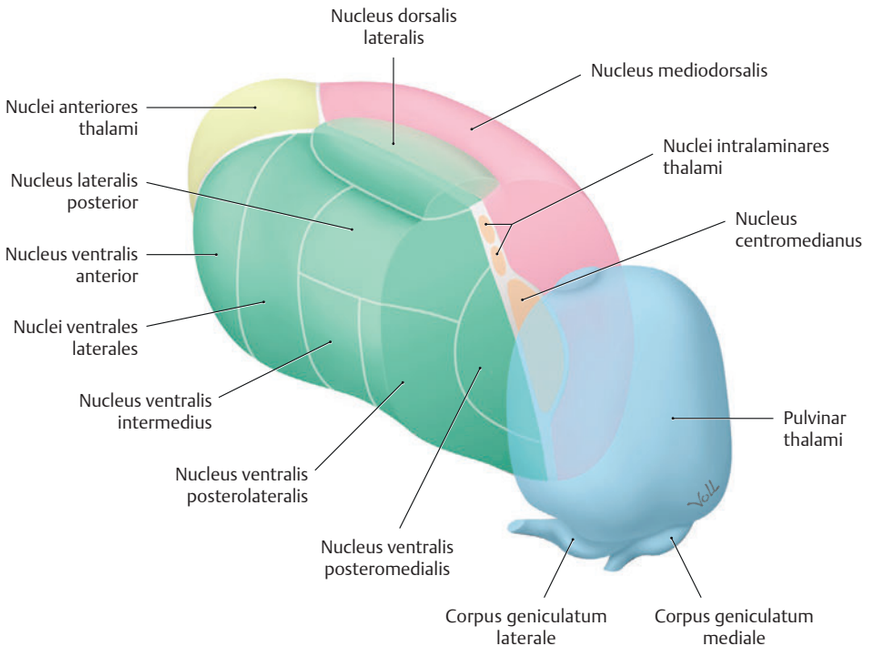


Fig. 4.28 **Functional organization of the thalamus**

Almost all of the sensory pathways are relayed via the thalamus and project to the cortex cerebri. Consequently, a lesion of the thalamus or its cortical projection fibers caused by a stroke or other disease leads to sensory disturbances. Although a diffuse kind of sensory perception may take place at the thalamic level (especially pain perception), cortical processing (by the telencephalon) is necessary in order to transform unconscious perception into conscious perception. The olfactory system is an exception to this rule, although its bulbus olfactorius is still an extension of the telencephalon.

Note: Major descending motor tracts from the cortex cerebri generally bypass the thalamus.

Fig. 4.29 **Spatial arrangement of the thalamic nuclear groups**

Left thalamus viewed from the lateral and occipital aspect. The thalamus is a collection of approximately 120 nuclei that process sensory information. They are broadly classified as specific or nonspecific:

- Specific nuclei and the fibers arising from them (thalamic radiation) have direct connections with specific areas of the *cortex cerebri*. The specific thalamic nuclei are subdivided into four groups:
  - Nuclei anteriores thalami (yellow)
  - Nuclei mediales thalami (red)
  - Nuclei ventrales thalami (green)
  - Nuclei dorsales thalami (blue).

The nuclei dorsales thalami are in contact with the corpora geniculata mediale and laterale. Located beneath the pulvinar thalami, these two nuclear bodies contain the *nuclei of the corpora geniculata media and lateral geniculate bodies*, and are collectively called the *metathalamus*. Like the pulvinar thalami, they belong to the category of specific thalamic nuclei.

- *Nonspecific nuclei* have no direct connections with the cortex cerebri. Part of a general arousal system, they are connected directly to the truncus encephali. The only nonspecific nuclei shown in this diagram (orange) are the nucleus centromedianus and the nuclei intralaminares thalami.

Table 4.5 **Clinically important connections of the thalamic nuclei**

Thalamic afferent	Thalamic nucleus	Thalamic efferents
Corpus mammillare (fasciculus mammallothalamicus)	Nucleus anterior thalami (NA)	Gyrus cinguli (limbic system)
Cerebellum, nucleus ruber	Nuclei ventrales laterales (VL)	Premotor cortex
Funiculus posterior, funiculus lateralis (somatosensory input from limbs and trunk)	Nucleus ventralis posterolateralis (VPL)	Gyrus postcentralis (sensory cortex)
Tractus trigeminothalamicus (somatosensory input from head)	Nucleus ventralis posteromedialis (VPM)	Gyrus postcentralis (sensory cortex)
Brachium colliculi inferioris (part of auditory pathway)	Corpus geniculatum mediale (body) (MGB)	Gyri temporales transversi (auditory cortex)
Tractus opticus	Corpus geniculatum laterale (body) (LGB)	Striate area (visual cortex)

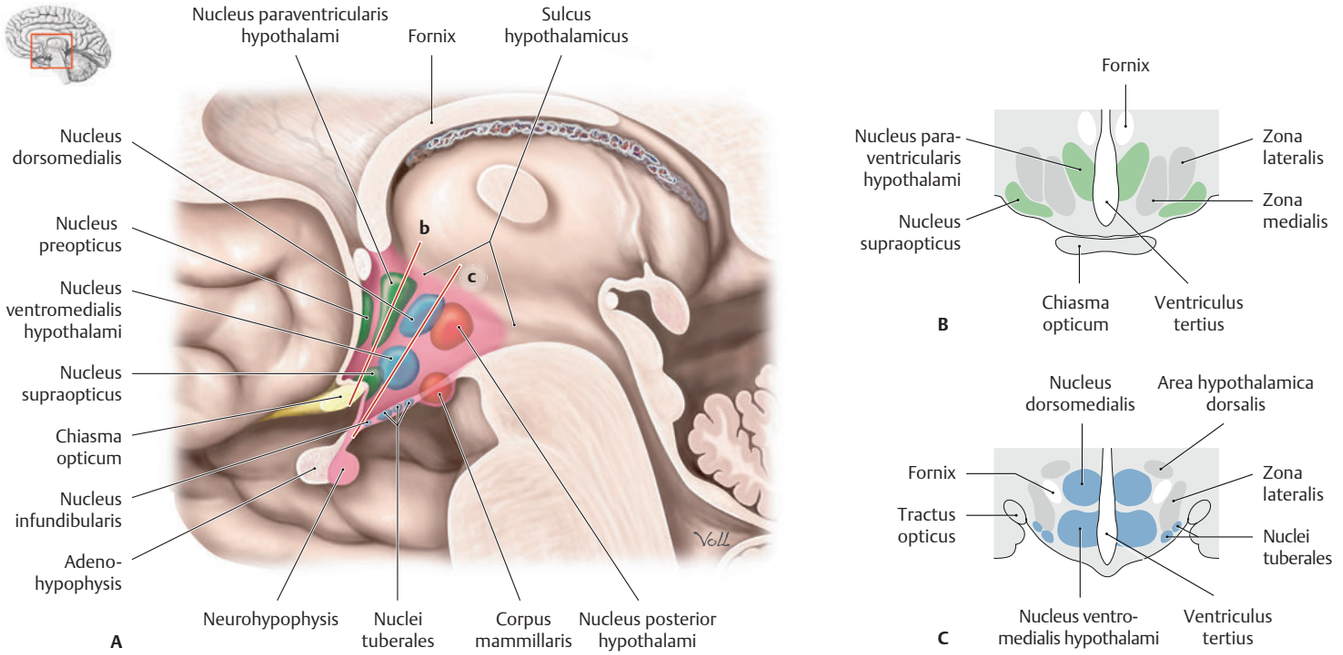


Fig. 4.30 **Nuclei in the right hypothalamus**
A Midsagittal section of the right hemispherium viewed from the medial side. **B, C** Coronal sections. The hypothalamus is a small nuclear complex located ventral to the thalamus and separated from it by the sulcus hypothalamicus. Despite its small size, the hypothalamus is the command center for all autonomic functions in the body. Only a few of the larger, more clinically important hypothalamic nuclei are mentioned in this unit. Three groups of nuclei are listed below in an oral-to-caudal sequence, and their functions are briefly described:

- The area hypothalamica rostralis (green) synthesizes the hormones released from the lobus posterior glandulae pituitariae (neurohypophysis), and consists of the:
  - nuclei preoptici,
  - nucleus paraventricularis hypothalami, and
  - nucleus supraopticus.
- The area hypothalamica intermedia (blue) controls hormone release from the lobus anterior glandulae pituitariae (adenohypophysis), and consists of the:
  - nucleus dorsomedialis,
  - nucleus ventromedialis hypothalami, and
  - nuclei tuberales.
- The area hypothalamica posterior (red) activates the sympathetic nervous system when stimulated. It consists of the:
  - nucleus posterior hypothalami and
  - nuclei mammillares located in the corpora mammillaria.

The coronal section (**C**) shows the further subdivision of the hypothalamus by the fornix into zonae lateralis and medialis. The three nuclear groups described above are part of the zona *medialis*, whereas the nuclei in the zona *lateralis* are not subdivided into specific groups (i.e., the zona lateralis takes the place of a nucleus). Bilateral lesions of the corpora mammillaria and their nuclei are manifested by *Korsakoff syndrome,* which is frequently associated with alcoholism (cause: vitamin B1 [thiamine] deficiency). The memory impairment that occurs in this syndrome mainly affects short-term memory, and the patient may fill in the memory gaps with fabricated information. A major neuropathological finding is the presence of hemorrhages in the corpora mammillaria, which are sectioned at autopsy to confirm the diagnosis.

Table 4.6 **Functions of the hypothalamus**

Region or nucleus	Function	Lesion
Anterior preoptic region	Maintains constant body temperature	Central hypothermia
Posterior region	Responds to temperature changes, e.g., sweating	Hypothermia
Midanterior and posterior regions	Activate sympathetic nervous system	Autonomic dysfunction
Paraventricular and anterior regions	Activate parasympathetic nervous system	Autonomic dysfunction
Nuclei supraopticus and paraventricularis	Regulate water balance	Diabetes insipidus Hyponatremia (low Na^+)
Nuclei anteriores	Regulate appetite and food intake	Lesion of medial part causes obesity Lesion of lateral part causes anorexia and emaciation

Truncus Encephali: Organization & External Structure

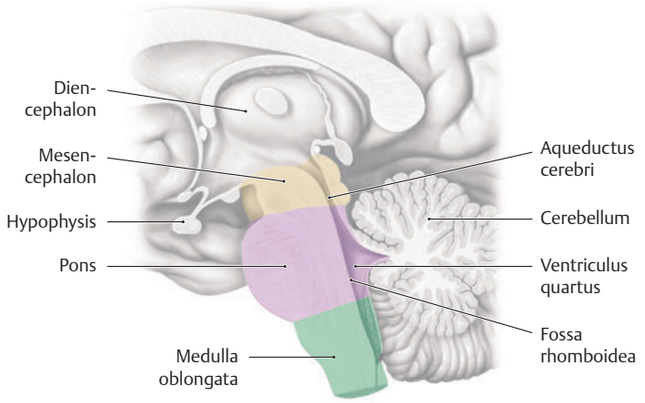


Fig. 4.31 **Division of the truncus encephali into levels**
Midsagittal section. The truncus encephali is divided macroscopically into three levels, with the bulge of the pons marking the boundary lines between the parts:

- Mesencephalon (midbrain)
- Pons
- Medulla oblongata

The three levels are easily distinguished from one another by gross visual inspection, although they are not differentiated in a functional sense. The *functional organization* of the truncus encephali is determined chiefly by the arrangement of the cranial nerve nuclei (see **pp. 116,** and **117**). Given the close proximity of nuclei and large fiber tracts in this region, even a small lesion of the truncus encephali (e.g., hemorrhage, tumor) may lead to extensive and complex alterations of sensorimotor function.

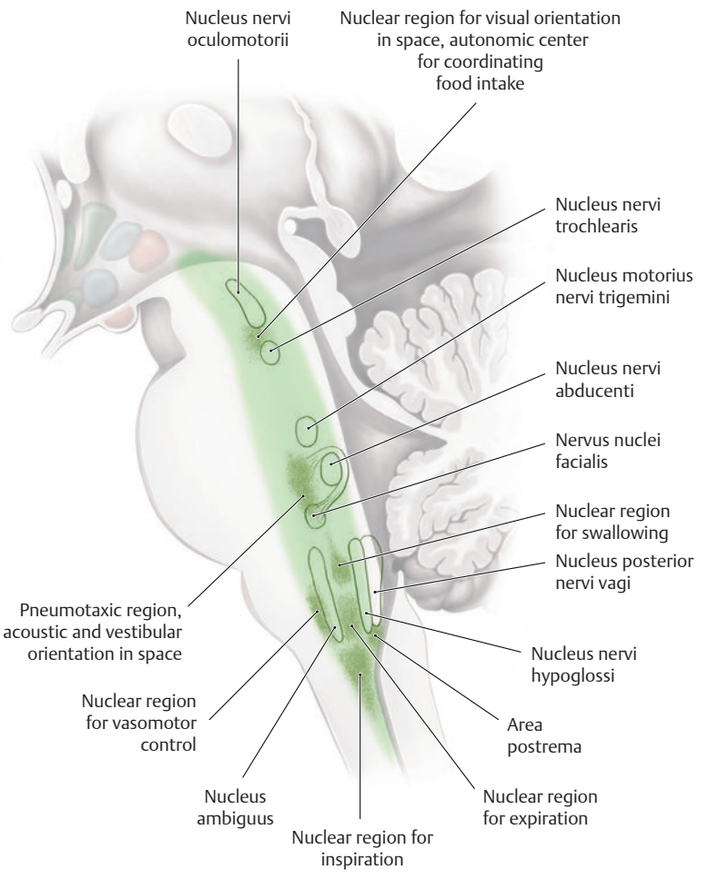


Fig. 4.32 **Structural-functional relationships in the formatio reticularis**
Midsagittal section of the truncus encephali viewed from the left side. While the nuclei nervorum cranialium, substantia nigra, and nucleus ruber have well-defined boundaries, as we have seen, the formatio reticularis (light green) is a relatively diffuse network of nerve cells and fibers in the truncus encephali, occupying the areas between the nuclei nervorum cranialium described above. It can be roughly divided into two main groups of nuclei:

- *Medial group* (specific nuclei labeled in the diagram): nuclei containing *large neurons* whose axons form long ascending and descending tracts.
- *Lateral group* (not individually labeled in the diagram): nuclei containing *small neurons* whose axons usually stay within the truncus encephali. They are therefore called "association areas."

Besides *respiratory and circulatory regulation,* the diffuse neuronal network of the formatio reticularis performs many other important autonomic functions.

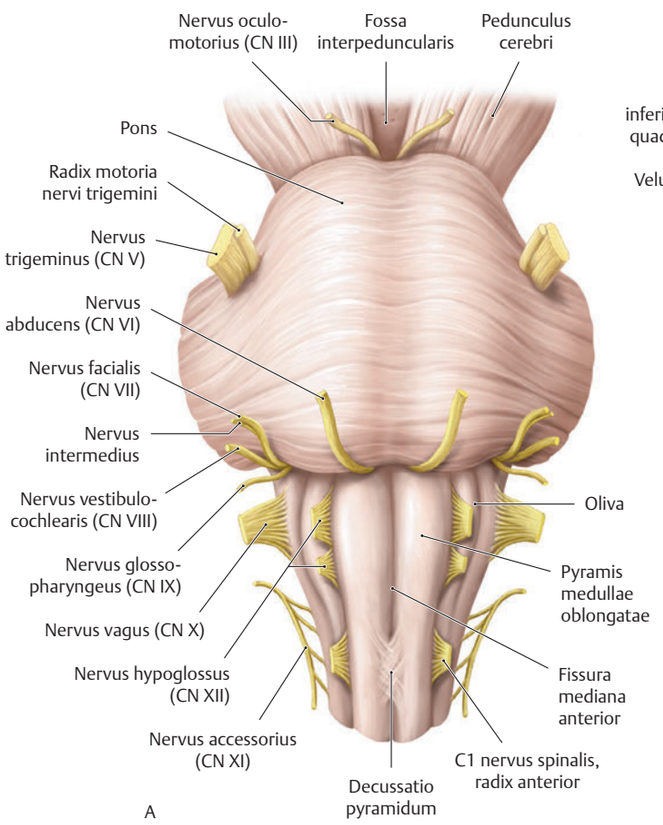


Fig. 4.33 **Truncus encephali**

A Anterior view. The sites of entry and emergence of the ten pairs of true nervi craniales (III—XII) are particularly well displayed in this view. *Note*: The nervus olfactorius (CN I) is a derivative of the telecephalon; the nervus opticus (CN II) is a derivative of the diencephalon. Note also the site below the pyramides where the pyramidal fibers cross over the midline from each side (decussatio pyramidum). Most of the axons of the large motor pathway for the trunk and limbs cross to the opposite side at this level. The nervi craniales are discussed in detail on pages 114 to 141.

B Posterior view. Since the cerebellum has been removed, we can see the fossa rhomboidea, which forms the floor of the ventriculus quartus. The surface of the fossa is raised by several nuclei nervorum cranialium, which bulge into the ventriculus quartus. The cerebellum is connected to the truncus encephali by three pedunculi cerebellares on each side:

- Pedunculus cerebellaris superior
- Pedunculus cerebellaris medius
- Pedunculus cerebellaris inferior

The pedunculi cerebellares superior and inferior border portions of the fossa rhomboidea and thus contribute to the boundaries of the ventriculus quartus.

C Left lateral view. In addition to the pedunculi cerebellares, this view displays the colliculi superior and inferior. Together with their counterparts on the right side, the colliculi form the lamina quadrigemina (see **B**), which is a prominent structure of the mesencephalon. The two colliculi superiores are part of the visual pathway, while the colliculi inferiores are part of the auditory pathway. The nervus trochlearis (CN IV) runs forward below the colliculus inferior, and is the only nervus cranialis that emerges from the posterior side of the truncus encephali. The oliva appears as a prominence on the side of the medulla oblongata. The nuclei within the oliva function as a relay station for the motor system.

Mesencephalon & Pons: Transverse Sections

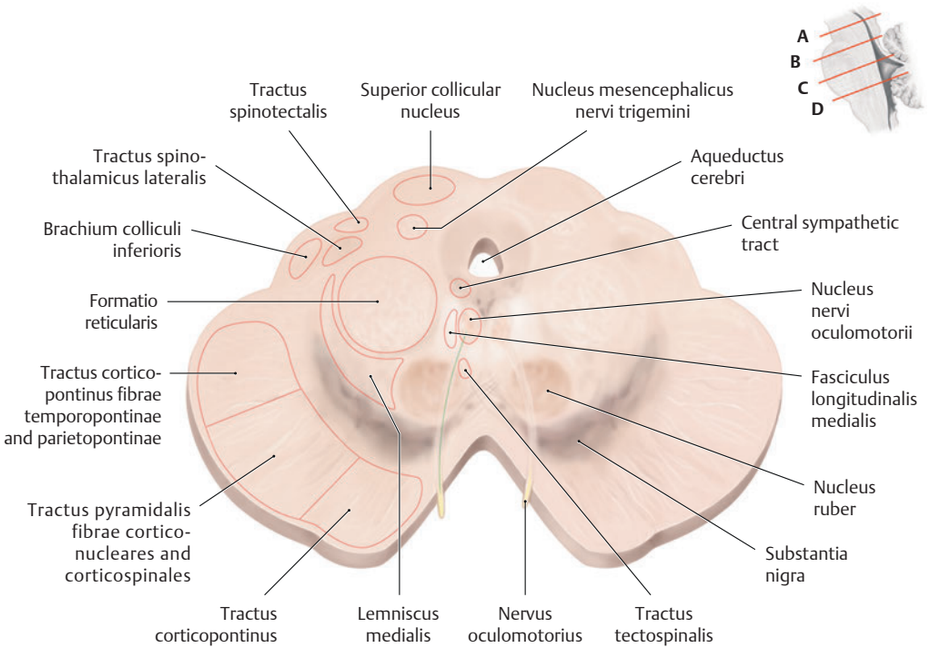


Fig. 4.34 **Transverse section through the mesencephalon (midbrain)**
Superior view.
Nuclei: The most rostral nucleus nervi cranialis is the relatively small *nucleus nervi oculomotorii*. In the same transverse plane is the *nucleus mesencephalicus nervi trigemini*; other trigeminal nuclei can be identified in sections at lower levels (see **Fig 4.36**). Unique in the CNS, the nucleus mesencephalicus nervi trigemini contains displaced pseudounipolar sensory neurons, closely related to the PNS neurons of the ganglion trigeminale (both populations are derived embryonically from the crista neuralis). The peripheral processes of these mesencephalic neurons are proprioceptors in the muscles of mastication. The *superior collicular nucleus* is part of the visual system. The *nucleus ruber* and *substantia nigra* are involved in coordination of motor activity. The nucleus ruber and all of the nuclei nervorum cranialium are located in the tegmentum of the mesencephalon, the colliculus superior is in the tectum (roof) of the mesencephalon, and the substantia nigra is in the pedunculus cerebri. Different parts of the formatio reticularis, a diffuse aggregation of nuclear groups (see p. 88), are visible here and in sections below.
Tracts: The tracts at this level run anterior to the nuclear regions. Prominent descending tracts seen at this level include the tractus pyramidalis and the fibrae corticonucleares that branch from it. Ascending tracts visible at this level include the tractus spinothalamicus lateralis and the lemniscus medialis, both of which terminate in the thalamus.

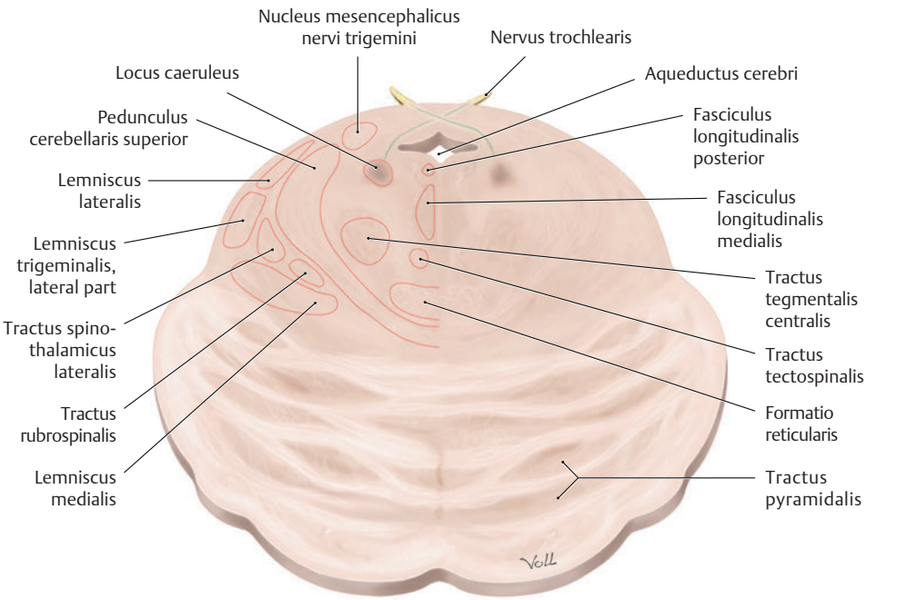


Fig. 4.35 **Transverse section through the upper pons**
Superior view.
Nuclei: The only nucleus nervi cranialis appearing in this plane of section is the nucleus mesencephalicus nervi trigemini. It can be seen that the fibers from the nucleus of the nervus trochlearis (CN IV) cross to the opposite side (decussate) while still within the truncus encephali.
Tracts: The ascending and descending tract systems are the same as in **Figs 4.34** and **4.36**. The tractus pyramidalis appears less compact at this level compared with the previous section due to the presence of intermingled nuclei pontis. This section cuts the tracts (mostly efferent) that exit the cerebellum through the pedunculus cerebellaris superior. The lemniscus lateralis at the posterior surface of the section is part of the auditory pathway. The relatively large fasciculus longitudinalis *medialis* extends from the mesencephalon (see **Fig 4.34**) into the medulla spinalis. It interconnects the brainstem nuclei and contains a variety of fibers that enter and emerge at various levels (*"highway of the brainstem nuclei"*). The smaller fasciculus longitudinalis *posterior* connects hypothalamic nuclei with the parasympathetic cranial nerve nuclei. The size and location of the nuclei of the formatio reticularis, which here are shown graphically within a compact area, vary with the plane of the section. This diagram indicates only the approximate location of the formatio reticularis, and other smaller nuclei and fibers may be found within these regions.

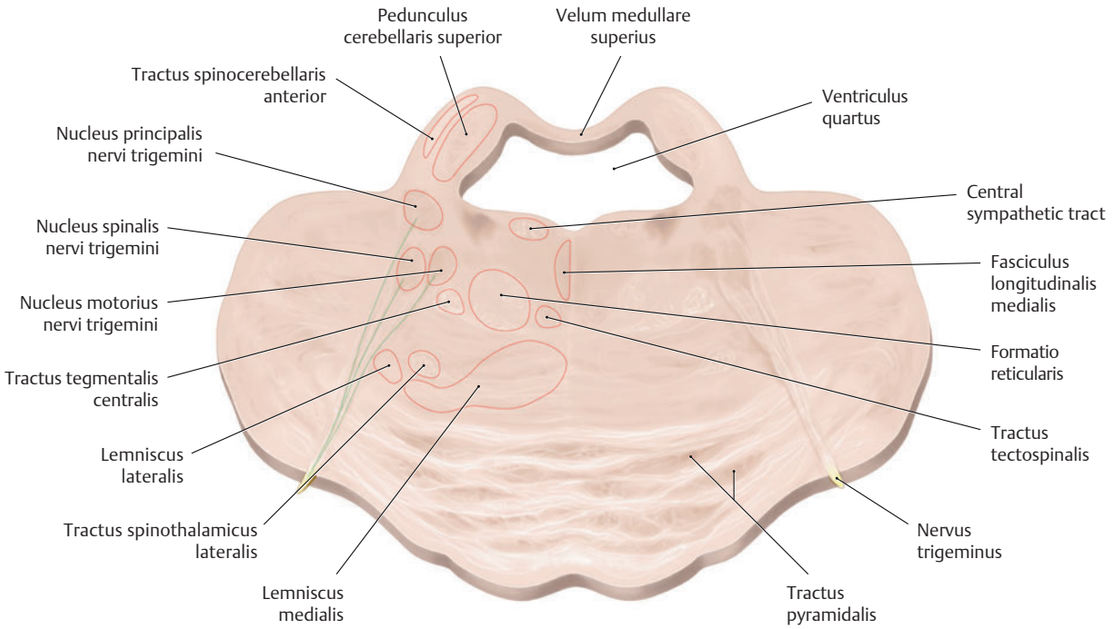


Fig. 4.36 **Transverse section through the midportion of the pons**
Nuclei: The nervus trigeminus leaves the truncus encephali at the midlevel of the pons, its various nuclei dominating the tegmentum pontis. The *nucleus principalis* nervi trigemini relays afferents for touch and discrimination, while the *nucleus spinalis* nervi trigemini relays pain and temperature fibers. The nucleus motorius nervi trigemini contains the motor neurons for the muscles of mastication.
Tracts: This section cuts the tractus spinocerebellaris anterior, which passes to the cerebellum, immediately dorsal to the pons.
CSF space: At this level the aqueductus cerebri has given way to the ventriculus quartus, which appears in cross-section. It is covered dorsally by the velum medullare superius.

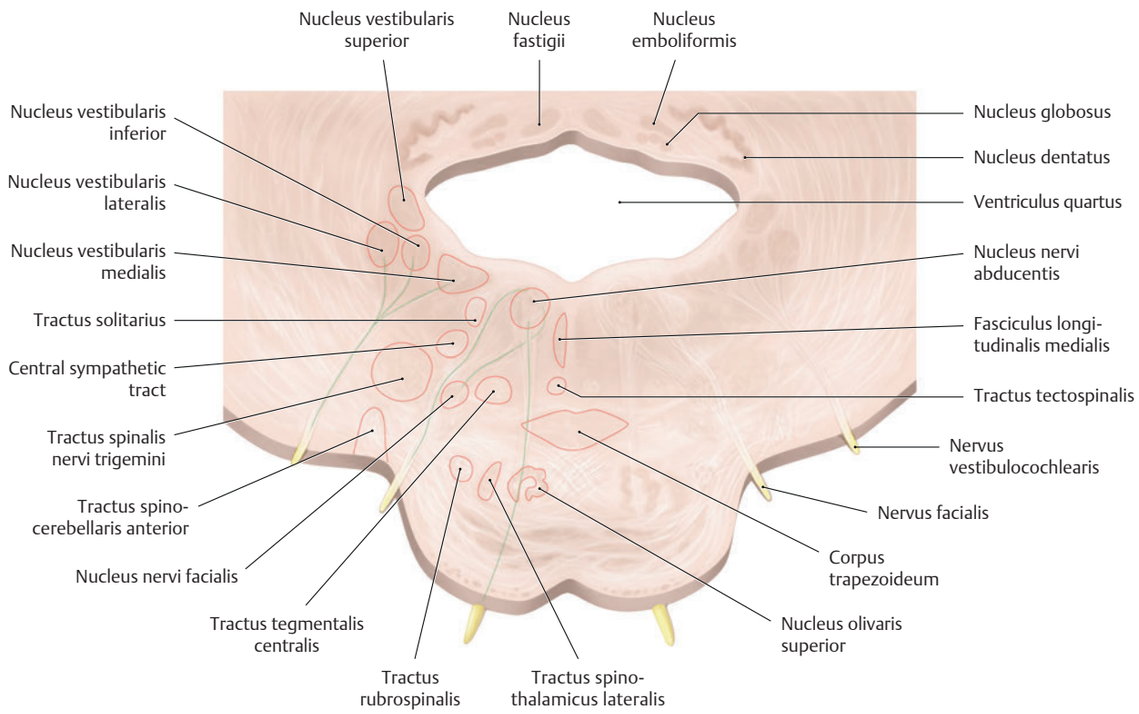


Fig. 4.37 **Transverse section through the lower pons (D)**
Nuclei: The lower pons contains a number of nuclei nervorum cranialium including the nuclei vestibulares, and cochleares, and nucleus nervi abducentis, and the nucleus nervi facialis. The fossa rhomboidea is covered dorsally by the cerebellum, whose nuclei also appear in this section—the nucleus fastigii, nucleus emboliformis, nucleus globosus, and nucleus dentatus.
Tracts: The corpus trapezoideum with its subnuclei is an important relay station and crossing point in the auditory pathway. The tractus tegmentalis centralis is an important pathway in the motor system.

Medulla Oblongata: Transverse Sections

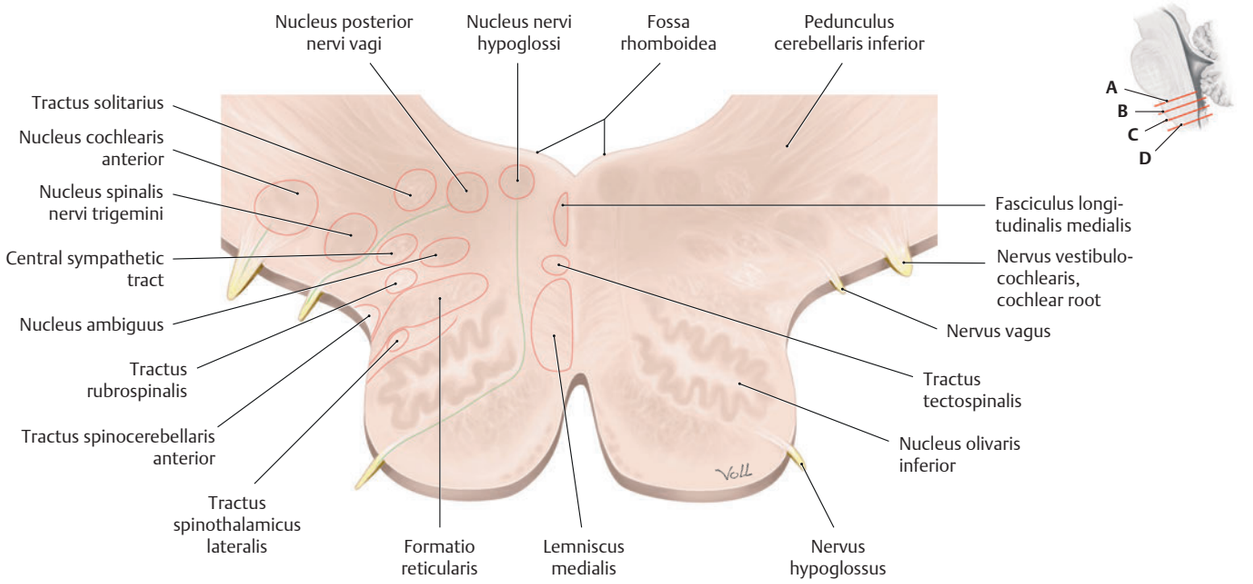


Fig. 4.38 **Transverse section through the upper medulla oblongata (A)**

Nuclei: The nuclei nervorum hypoglossi, vagi, vestibulocochlearis, and the nucleus spinalis nervi trigemini appear in the *posterior* part of the medulla oblongata. The nucleus olivaris inferior, which belongs to the motor system, is located in the *anterior* part of the medulla oblongata. The formatio reticularis is interposed between the nuclei nervorum cranialium and the nucleus olivaris inferior. It appears in all the transverse sections of this section.

Tracts: Most of the ascending and descending tracts are the same as in **Fig 4.37**. A new structure appearing at this level is the *pedunculus cerebellaris inferior*, through which afferent tracts pass to the cerebellum.

CSF space: The floor of the ventriculus quartus is the rhomboid fossa, which marks the dorsal boundary of this section.

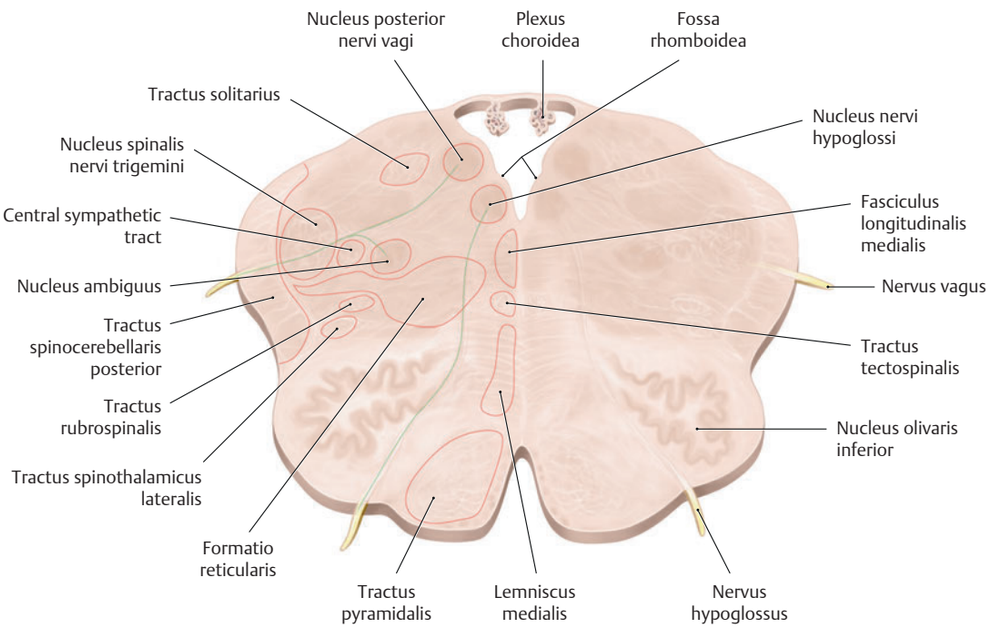


Fig. 4.39 **Transverse section just above the middle of the medulla oblongata (B)**

Nuclei: The only nuclei nervorum cranialium visible at this level are those of the nervus hypoglossus, nervus vagus, and nervus trigeminus, appearing in the posterior medulla. The lower portion of the nucleus olivaris inferior appears in the anterior medulla.

Tracts: The ascending and descending tracts are the same as in **Fig 4.37**. Ascending sensory tracts (from nuclei gracilis and cuneatus) decussate in the *lemniscus medialis*. The tractus solitarius carries the gustatory fibers of nervi craniales V, VII, and X. Posterolateral to it is the *nucleus tractus solitarii* (not shown). The *tractus pyramidalis* again appears as a compact structure at this level due to the absence of interspersed nuclei and decussating fibers.

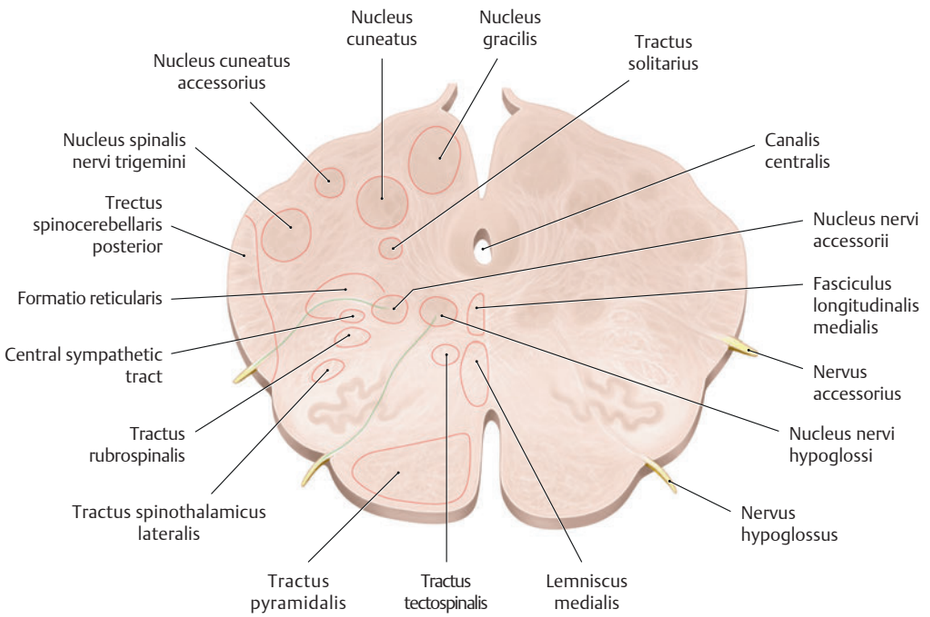


Fig. 4.40 **Transverse section just below the middle of the medulla oblongata (C)**

Nuclei: The nuclei nervorum hypoglossi, vagi, and trigemini appear at this level. The irregular outline of the nucleus olivaris inferior is still just visible in the anterior medulla. The nuclei that relay signals from the funiculus posterior—the nucleus cuneatus and nucleus gracilis—appear prominently in the posterior part of the section. The tracts that arise from these nuclei decussate in the lemniscus medialis (see above).

Tracts: The ascending and descending tracts correspond to those in the previous figures in this section. The fossa rhomboidea, which is the floor of the ventriculus quartus, has narrowed substantially at this level to become the canalis centralis.

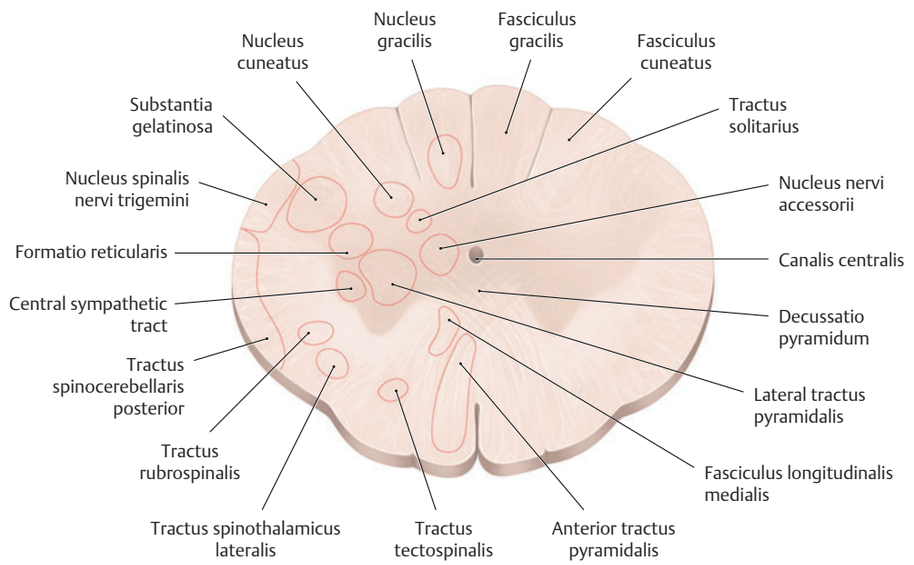


Fig. 4.41 **Transverse section through the lower medulla oblongata (D)**

The medulla oblongata is continuous with the medulla spinalis at this level, showing no distinct transition.

Nuclei: The nuclei nervorum cranialium visible at this level are the nucleus spinalis nervi trigemini and the nucleus nervi accessorii. This section passes through the caudal ends of the nuclei in the relay station of the funiculus posterior—the nucleus cuneatus and nucleus gracilis.

Tracts: The ascending and descending tracts correspond to those in the previous figures in this section. The section passes through the decussatio pyramidum, and we can now distinguish the anterior tractus pyramidalis (uncrossed) from the lateral tractus pyramidalis (crossed).

CSF space: This section passes through a portion of the canalis centralis, which is markedly smaller at this level than in **Fig 4.40**. It may even be obliterated at some sites, but this has no clinical significance.

Liquor Cerebrospinalis (CSF) Spatia & Ventriculi

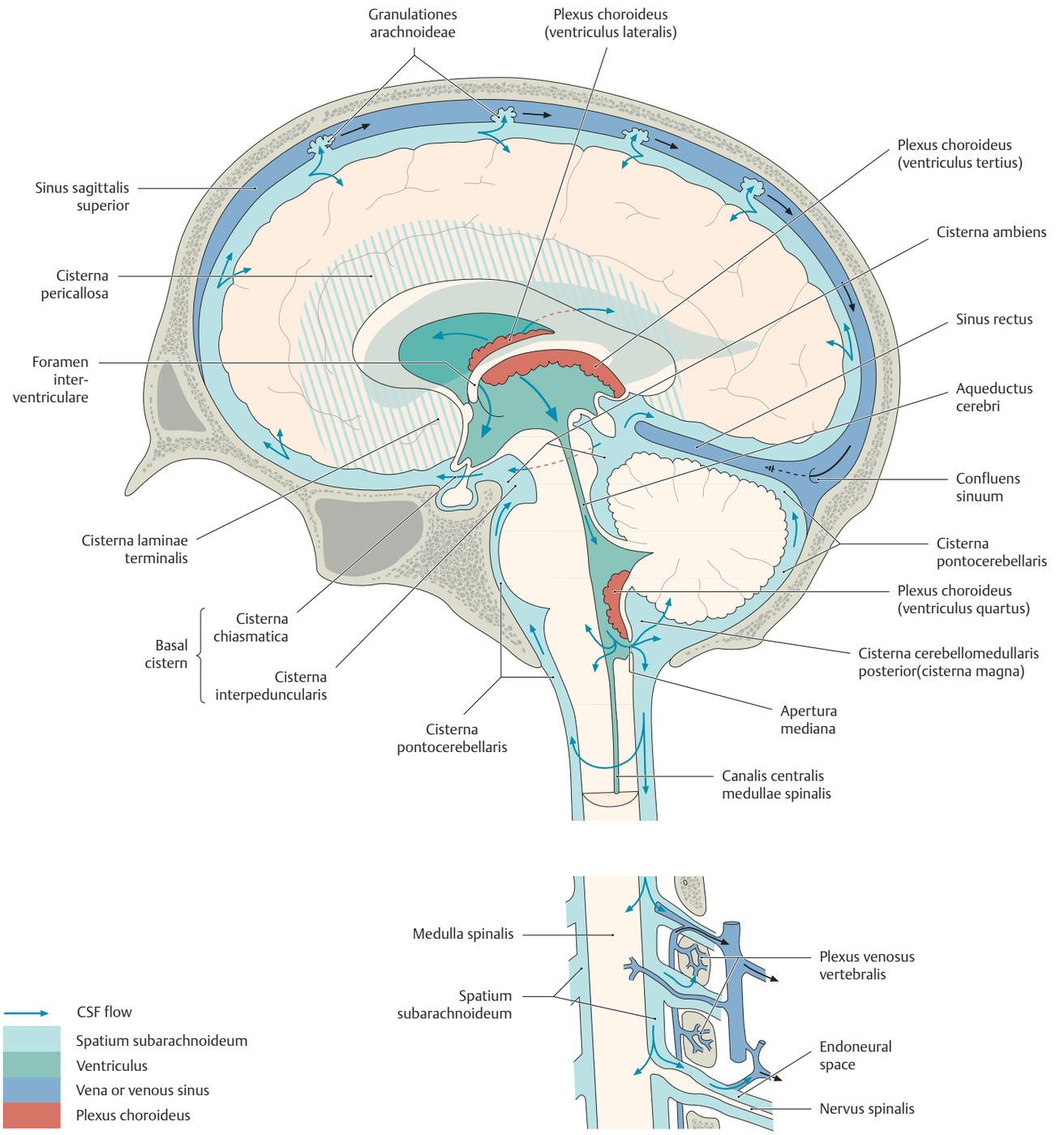


Fig. 4.42 **CSF spaces**
Schematic midsagittal section. Medial view of right hemispherium. The encephalon and medulla spinalis are suspended in CSF. CSF is located in the spatium subarachnoideum enclosed by the meningeal layers surrounding the encephalon and medulla spinalis. The cerebral ventriculi and spatium subarachnoideum have a combined capacity of approximately 150 mL of CSF (80% in spatium subarachnoideum, 20% in ventriculi). This volume is completely replaced two to four times daily. CSF is produced in the plexus choroideus (red) and is present in each of the four cerebral ventriculi. It flows from the ventriculi through the aperturae mediana and lateralis (not shown) into the spatium subarachnoideum. Most CSF drains from the spatium subarachnoideum through the granulationes arachnoideae into the sinus durae matris. Smaller amounts drain along the proximal portions of the nervi spinales into plexus venosi or lymphatic pathways. Obstruction of CSF drainage will cause a rapid rise in intracranial pressure due to the high rate of CSF turnover.

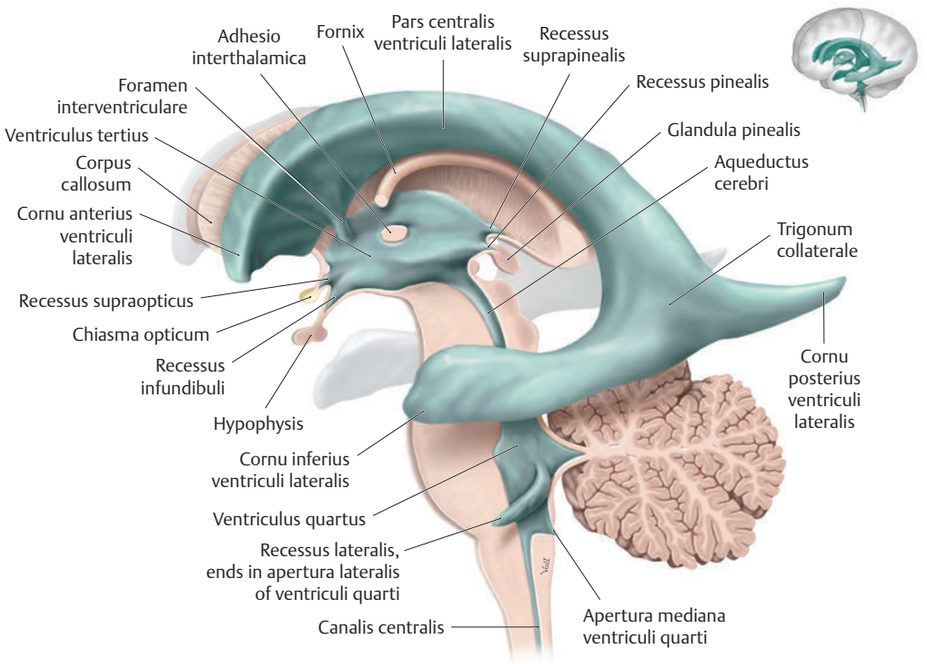
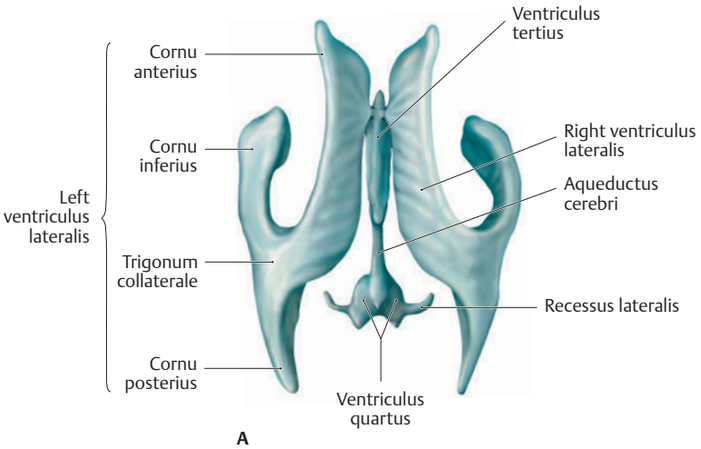


Fig. 4.43 **Ventricular system with its neighboring structures**
Left lateral view. The ventricular system is a greatly expanded and convoluted tube that represents a continuation of the canalis centralis into the enephalon. There are *four cerebral ventriculi*, or cavities, filled with liquor cerebrospinalis and lined by a specialized epithelium, the ependyma. The four ventriculi are as follows:

- The *two* ventriculi laterales, each of which communicates through a foramen interventriculare with the
- ventriculus tertius, which in turn communicates through the aqueductus cerebri with the
- ventriculus quartus. This ventriculus communicates with the spatium subarachnoideum (see **Fig 4.42**).

The largest ventriculi are the ventriculi laterales, each of which consists of a cornu anterius, inferius, and posterius and a pars centralis. Certain portions of the ventricular system can be assigned to specific parts of the brain: the cornu anterius (frontale) to the lobus frontalis of the cerebrum, the cornu inferius (temporale) to the lobus temporalis, the cornu posterius (occipitale) to the lobus occipitalis, the ventriculus tertius to the diencephalon, the aqueductus to the mesencephalon (midbrain), and the ventriculus quartus to the rhombencephalon (hindbrain).
Certain diseases (e.g., atrophy of brain tissue in Alzheimer's disease and internal hydrocephalus) are characterized by abnormal enlargement of the ventricular system and are diagnosed from the size of the ventriculi in sectional images of the brain.



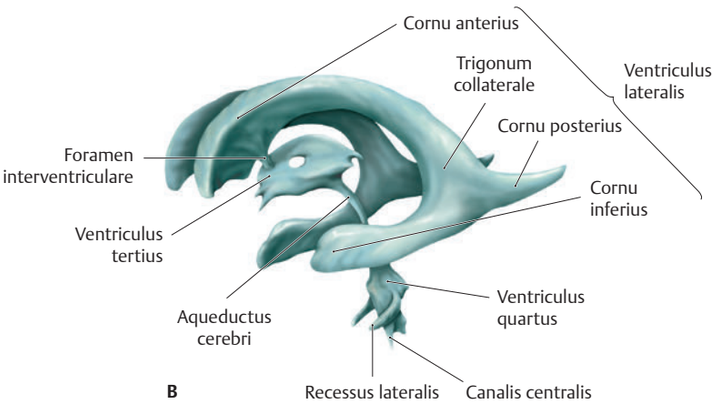


Fig. 4.44 **Cast of the ventricular system**
A Superior view. **B** Left lateral view.
These cast specimens demonstrate the four ventricular cavities and their connections.
Hydrocephalus is an excess of liquor cerebrospinalis (CSF) in the ventriculi of the encephalon. It usually occurs due to partial obstruction of the flow of CSF between the ventriculi or between the ventriculi and other parts of the brain. Excess CSF in the ventriculi causes them to dilate and exert pressure on the surrounding cortex. In infants, the bones of the calvaria separate giving the characteristic increase in head size.

Arteries of the Encephalon

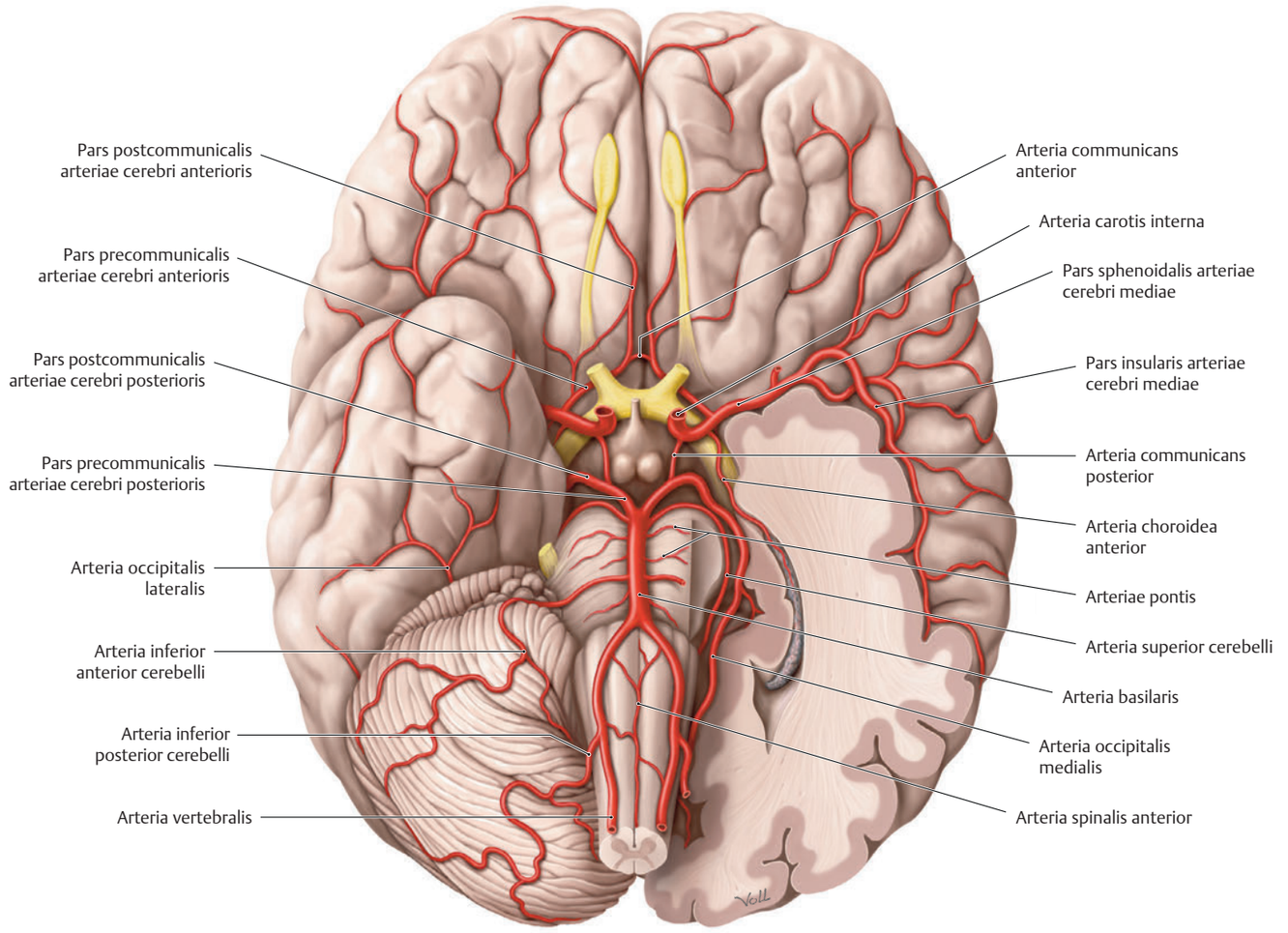


Fig. 4.45 **Arteries at the base of the brain**
The cerebellum and lobus temporalis have been removed on the left side to display the course of the arteria cerebri posterior. This view was selected because most of the arteries that supply the encephalon enter the cerebrum from its basal aspect (also see **Fig. 3.17** for the circulus arteriosus cerebri).
Note: The three principal arteries of the cerebrum, the arteriae cerebralis anterior, media and posterior, arise from different sources. The arteriae cerebri anterior and media are branches of the arteria carotis interna, while the arteriae cerebri posteriores are terminal branches of the arteria basilaris. The arteriae vertebrales, which fuse to form the arteria basilaris, distribute branches to the medulla spinalis, truncus encephali, and cerebellum (arteria spinalis anterior, arteria spinalis posterior, arteria superior cerebelli, and arteriae inferior anterior and posterior cerebelli).

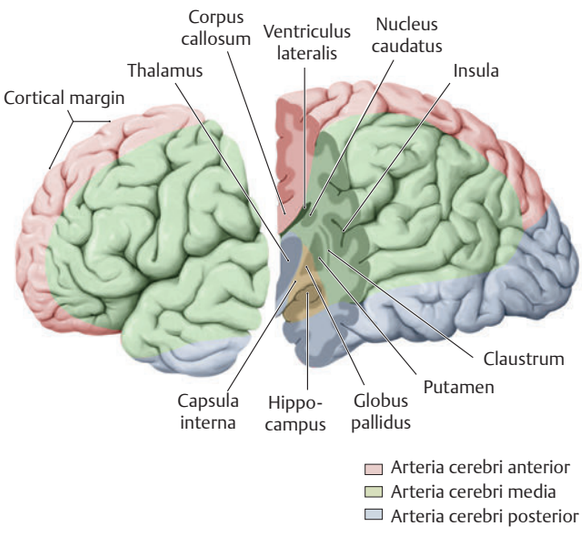


Fig. 4.46 **Cerebral arteries: Distribution areas**
Lateral view of the left hemispherium. The central gray and white matter have a complex blood supply (yellow) that includes the arteria choroidea anterior.

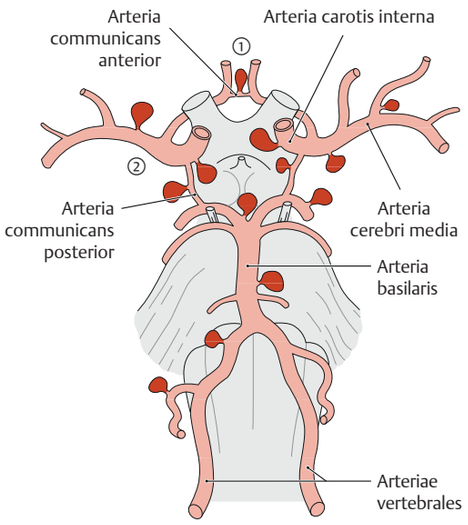


Fig. 4.47 **Sites of berry aneurysms at the base of the encephalon** (after Bähr and Frotscher)
The rupture of congenital or acquired arterial aneurysms at the base of the encephalon is the most frequent cause of subarachnoid hemorrhage and accounts for approximately 5% of all strokes. These are abnormal saccular dilations of the circulus arteriosus cerebri and are especially common at the site of branching. When one of these thin-walled aneurysms ruptures, arterial blood escapes into the spatium subarachnoideum. The most common site is the junction between the arteriae cerebri anterior and communicans anterior (1); the second most likely site is the branching of the arteria communicans posterior from the arteria carotis interna (2).

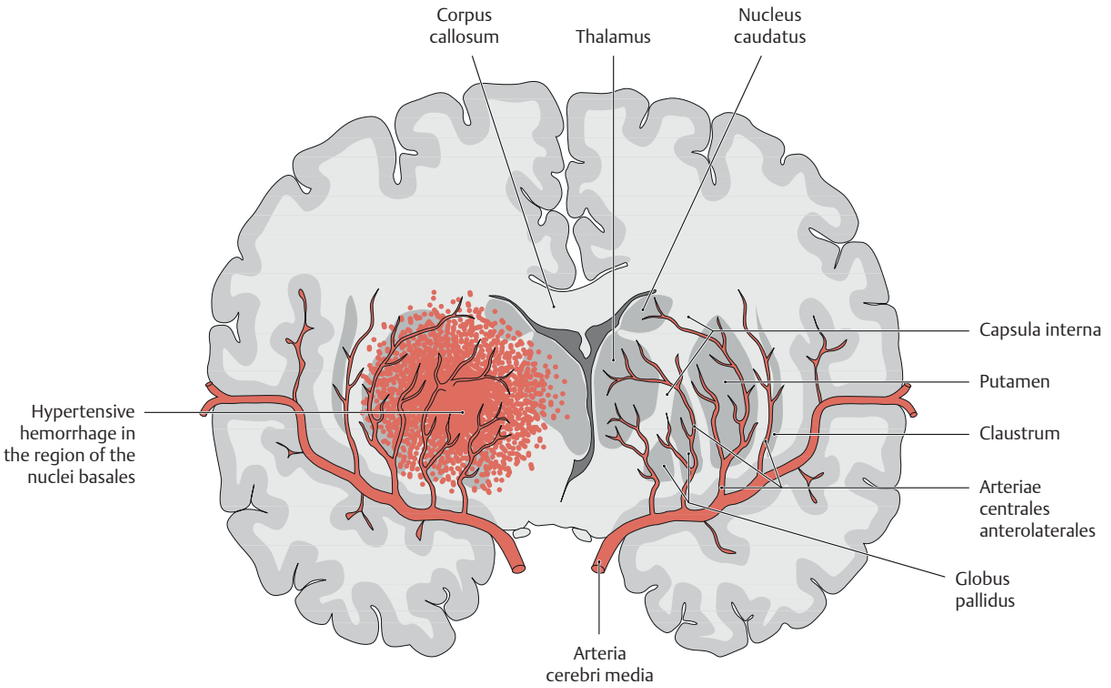


Fig. 4.48 **Intracerebral hemorrhage**
Coronal section at the level of the thalamus. Unlike the *extracerebral* hemorrhages described above, *intracerebral* hemorrhage occurs when damaged arteries bleed directly *into the substance of the brain*. This distinction is of very great clinical importance because extracerebral hemorrhages can be controlled by surgical hemostasis of the bleeding vessel, whereas intracerebral hemorrhages cannot. The most frequent cause of intracerebral hemorrhage (hemorrhagic stroke) is hypertension (high blood pressure). Because the soft brain tissue offers very little resistance, a large hematoma may form within the brain. The most common sources of intracerebral bleeding are specific branches of the arteria cerebri media—the arteriae centrales anterolaterales pictured here (known also as the "stroke arteries"). The hemorrhage causes a cerebral infarction (death of brain tissue) in the region of the capsula interna, one effect of which is to disrupt the tractus pyramidalis, which passes through the capsula. The loss of tractus pyramidalis function below the lesion is manifested clinically by spastic paralysis of the limbs on the side of the body *opposite* to the injury (the tractus pyramidales cross below the level of the lesion). The hemorrhage is not always massive, and smaller bleeds may occur in the territories of the three main cerebral arteries, producing a typical clinical presentation (see **Fig. 4.55**).

Veins of the Encephalon: Venae Superficiales & Profundae

Because the veins of the encephalon do not run parallel to the arteries, marked differences are noted between the regions of arterial supply and venous drainage. While all of the cerebral arteries enter the encephalon at its base, venous blood is drained from the entire surface of the encephalon, including the base, and also from the interior of the encephalon by two groups of veins: *the venae superficiales cerebri* and the *venae profundae cerebri*. The venae superficiales drain blood from the cortex cerebri (via cortical veins) and substantia alba (via medullary veins) directly into the sinus durae matris. The venae profundae drain blood from the deeper portions of the substantia alba, nuclei basales, corpus callosum, and diencephalon into the vena magna cerebri, which enters the sinus rectus. The two venous regions (those of the venae superficiales and and venae profundi) are interconnected by numerous intracerebral anastomoses (see **Fig 4.52**).

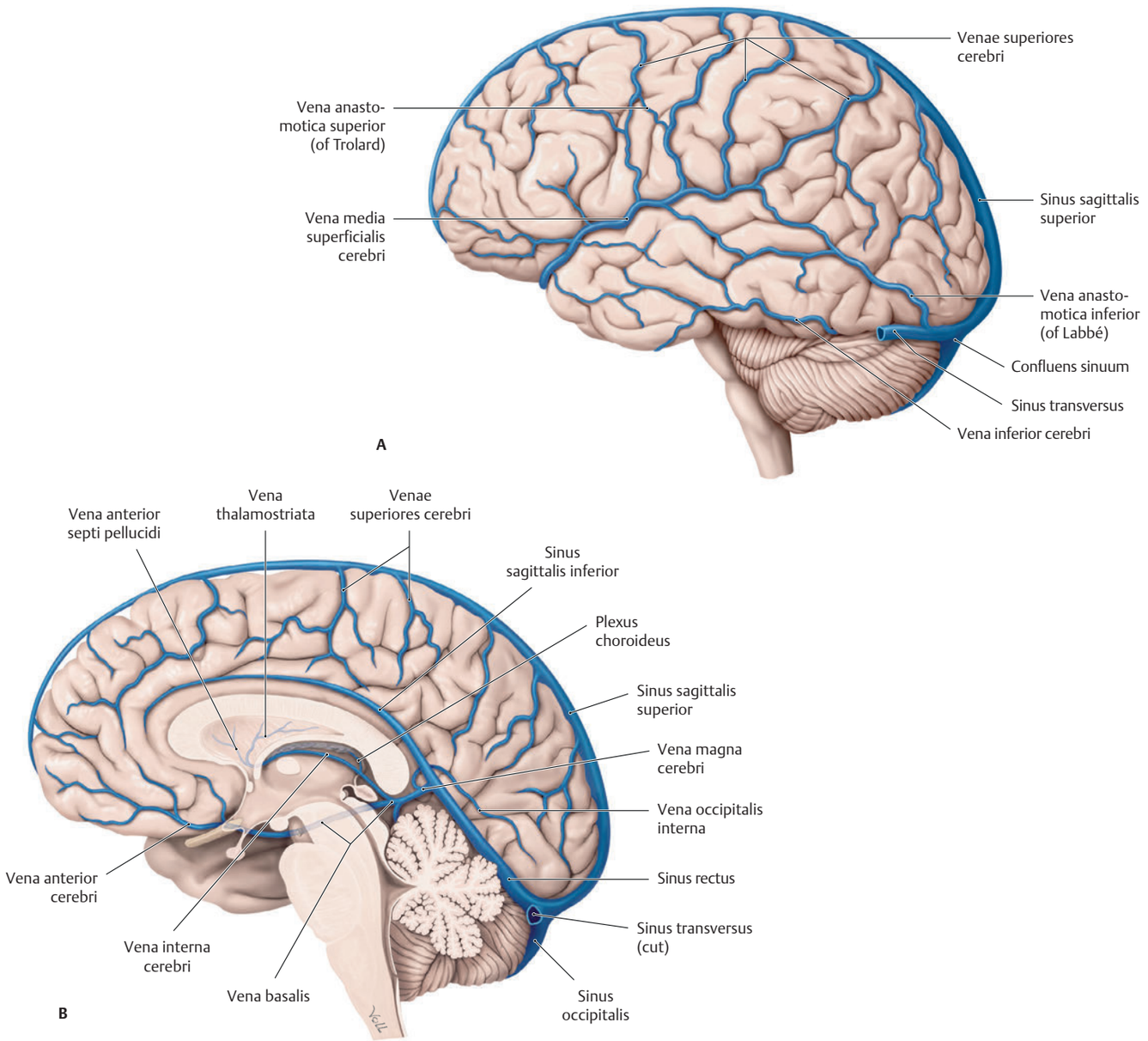


Fig. 4.49 **Venae superficiales cerebri (superficial cerebral veins)**
A Left lateral view. **B** Medial view.
A, B The venae superficiales cerebri drain blood from the short cortical veins and long medullary veins in the substantia alba (see **Fig 4.52**) into the sinus durae matris. Their course is extremely variable, and veins in the spatium subarachnoideum do not follow arteries, gyri, or sulci. Consequently, only the most important of these vessels are named here.

Just before terminating in the sinus durae matris, the veins leave the spatium subarachnoideum and run a short subdural course between the dura mater and arachnoidea mater. These short subdural venous segments are called *bridging veins*. The bridging veins have great clinical importance because they may be ruptured by head trauma, resulting in a subdural hematoma (see p. 103).

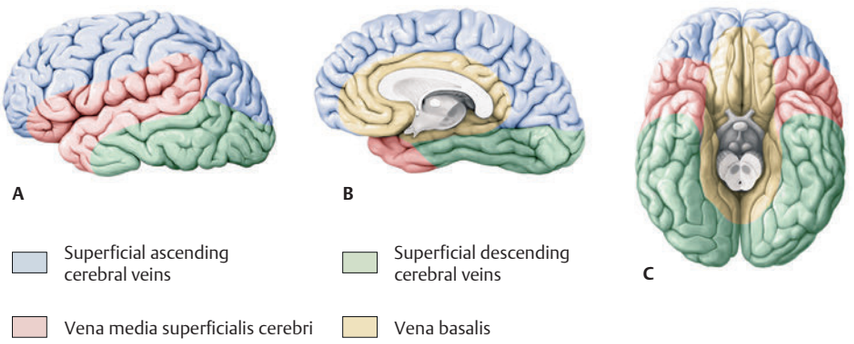


Fig. 4.50 **Regions drained by the venae superficiales cerebri**
A Left lateral view, **B** view of the facies medialis of the right hemispheri um, **C** basal view.
The veins on the lateral surface of the encephalon are classified by their direction of drainage as ascending (draining into the sinus sagittalis superior) or descending (draining into the sinus transversus). The vena media superficialis cerebri drains into both the sinus cavernosus and transversus.

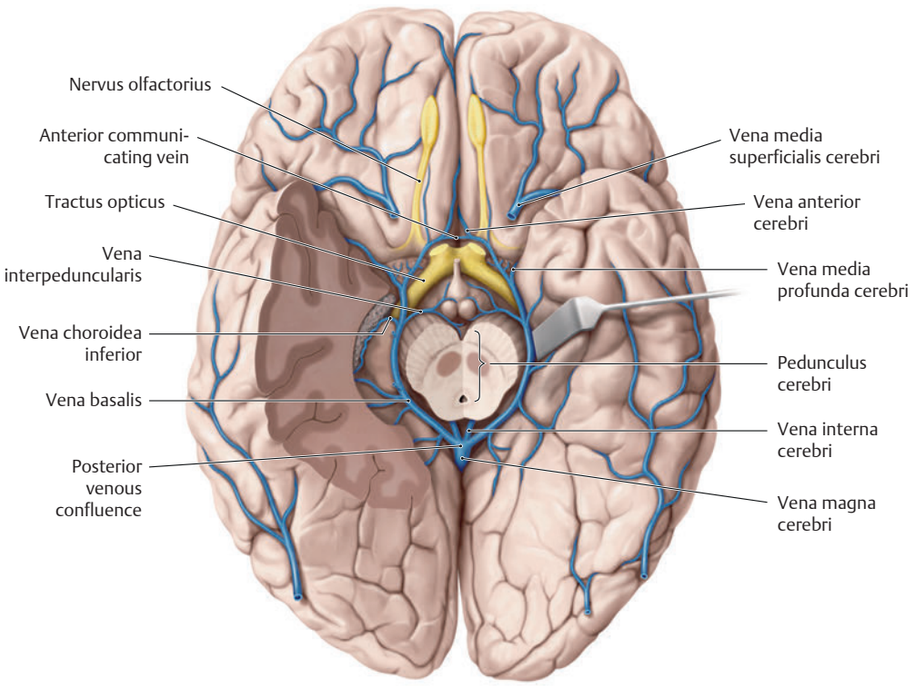


Fig. 4.51 **Basal cerebral venous system**
The basal cerebral venous system drains blood from both venae superficiales and profundae cerebri. A venous circle formed by the venae basales (of Rosenthal) exists at the base of the encephalon, analogous to the circulus arteriosus cerebri. The vena basalis is formed in the substantia perforata anterior by the union of the venae anteriores cerebri and venae mediae profundae cerebri. Following the course of the tractus opticus, the vena basalis runs posteriorly around the pedunculus cerebri and unites with the vena basalis from the opposite side on the dorsal aspect of the mesencephalon. The two venae internae cerebri also terminate at this venous junction, the posterior venous confluence. This junction gives rise to the midline vena magna cerebri, which enters the sinus rectus. The vena basalis receives tributaries from deep brain regions in its course (e.g., veins from the thalamus and hypothalamus, plexus choroideus of the cornu inferius, etc.). The two venae anteriores cerebri are interconnected by the anterior communicating vein, creating a closed, ring-shaped drainage system.

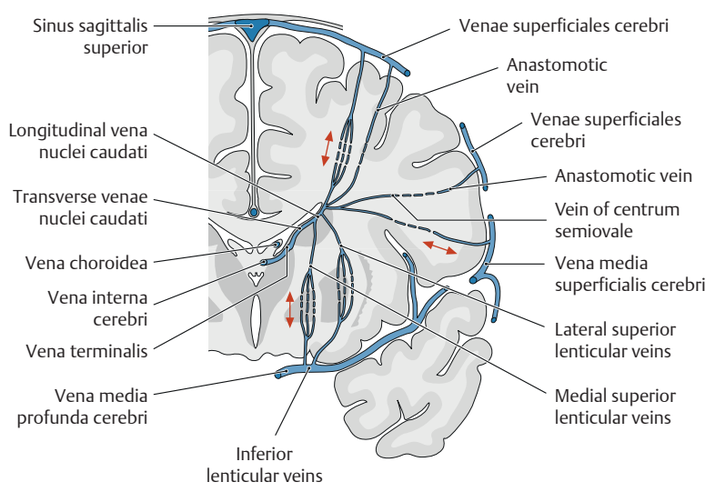


Fig. 4.52 ***Anastomoses between the venae superficiales and profundae cerebri*** **Basal cerebral venous system**
Transverse section through the left hemisphere, anterior view. The venae superficiales cerebri communicate with the venae profundae cerebri through the anastomoses shown here. Flow reversal (double arrows) may occur in the boundary zones between two territories.

Blood Vessels of the Encephalon: Cerebrovascular Disease

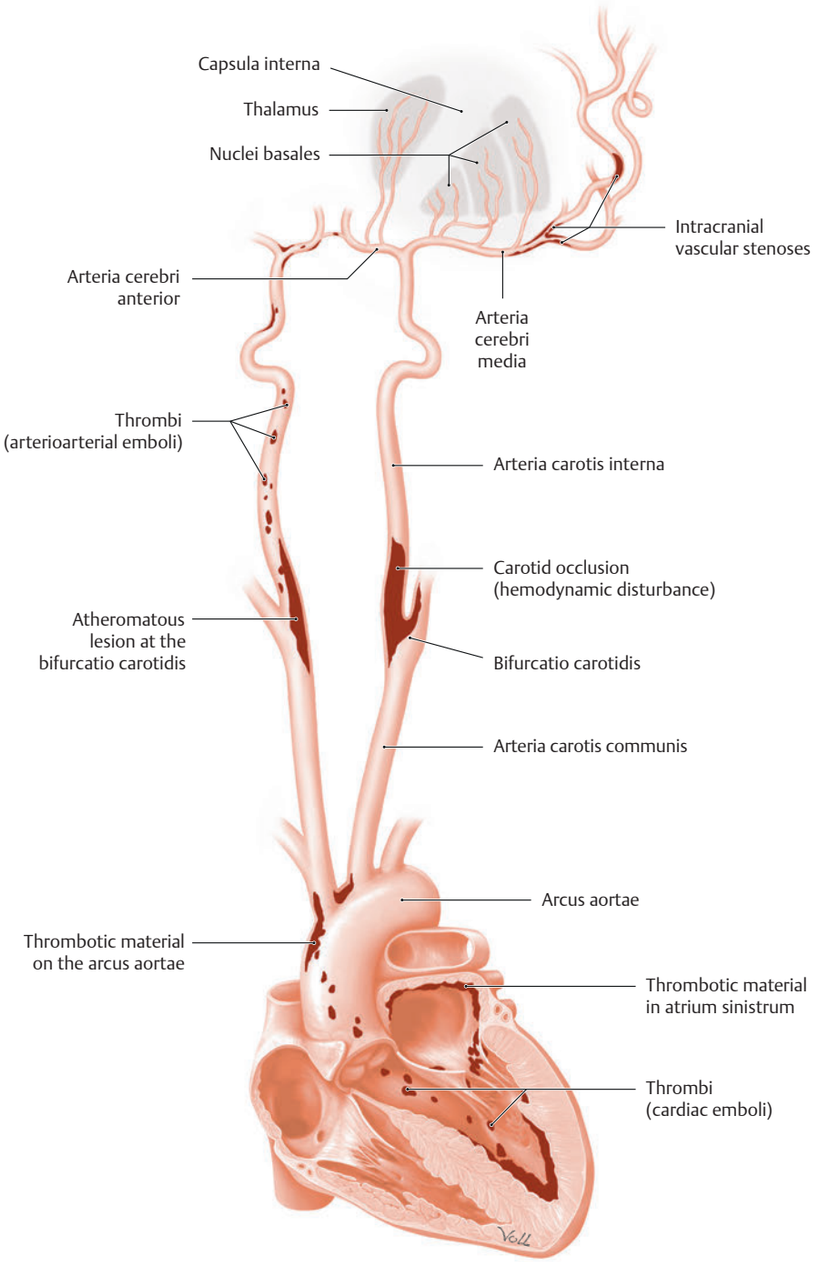


Fig. 4.53 **Frequent causes of cerebrovascular disease** (after Mumenthaler)

Disturbances of cerebral blood flow that deprive the encephalon of oxygen (cerebral ischemia) are the most frequent cause of central neurological deficits. The most serious complication is stroke: the vast majority of all strokes are caused by cerebral *ischemic* disease. Stroke has become the third leading cause of death in western industrialized countries (approximately 700,000 strokes occur in the United States each year). Cerebral ischemia is caused by a prolonged diminution or interruption of blood flow and involves *the distribution area of the arteria carotis interna* in up to 90 % of cases. Much less commonly, cerebral ischemia is caused by an obstruction of venous outflow due to cerebral venous thrombosis (see **Fig. 4.54**). A decrease of arterial blood flow in the carotid system most commonly results from an embolic or local thrombotic occlusion. Most emboli originate from atheromatous lesions at the bifurcatio carotidis (arterioarterial emboli) or from the expulsion of thrombotic material from the ventriculus sinister (cardiac emboli). Blood clots (thrombi) may be dislodged from the heart as a result of valvular disease or atrial fibrillation. This produces emboli that may be carried by the bloodstream to the encephalon, where they may cause the functional occlusion of an artery supplying the encephalon. The most common example of this involves all of the distribution region of the arteria cerebri media, which is a direct continuation of the arteria carotis interna.

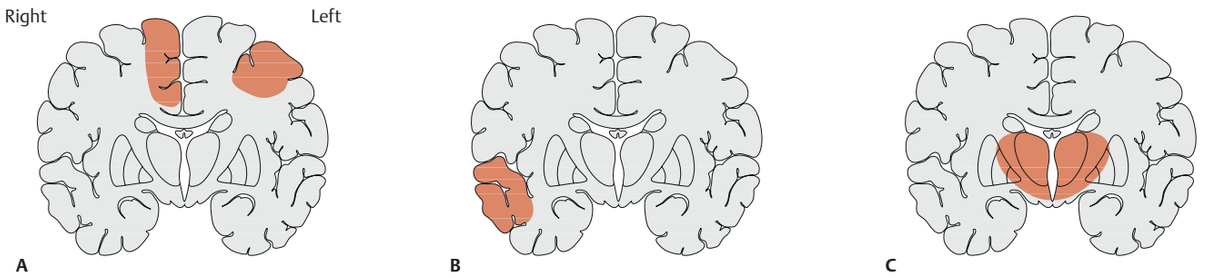


Fig. 4.54 **Cerebral venous thrombosis**
Coronal section, anterior view. The cerebral veins, like the cerebral arteries, serve specific territories (see pp. 258 and 260). Though much less common than decreased arterial flow, the obstruction of venous outflow is an important potential cause of ischemia and infarction. With a thrombotic occlusion, for example, the quantity of blood and thus the venous pressure are increased in the tributary region of the occluded vein. This causes a drop in the capillary pressure gradient, with an increased extravasation of fluid from the capillary bed into the brain tissue (edema). There is a concomitant reduction of arterial inflow into the affected region, depriving it of oxygen. The occlusion of specific cerebral veins (e.g., due to cerebral venous thrombosis) leads to brain infarctions (stroke) at characteristic locations:

A Venae superiores cerebri: Thrombosis and infarction in the areas drained by the:

- Medial venae superiores cerebri (right, *symptoms:* contralateral lower limb weakness);
- Posterior venae superiores cerebri (left, *symptoms:* contralateral hemiparesis).

Motor aphasia occurs if the infarction involves the motor speech center in the dominant hemisphere.

B Venae inferiores cerebri: Thrombosis of the right venae inferiores cerebri leads to infarction of the right lobus temporalis (*symptoms:* sensory aphasia, contralateral hemianopia).

C Venae internae cerebri: Bilateral thrombosis leads to a symmetrical infarction affecting the thalamus and nuclei basales. This is characterized by a rapid deterioration of consciousness ranging to coma.

Because the sinus durae matris have extensive anastomoses, a limited occlusion affecting part of a sinus often does not cause pronounced clinical symptoms, unlike the venous thromboses described here.

Vascular territory	Neurological symptoms	
Arteria cerebri anterior	Hemiparesis (with or without hemisensory deficit)	Bladder dysfunction
Arteria cerebri media	Hemiparesis (with or without hemisensory deficit) mainly affecting the arm and face (Wernicke-Mann type)	Aphasia
Arteria cerebri posterior	Hemisensory losses	Hemianopia

Fig. 4.55 **Cardinal symptoms of occlusion of the three main cerebral arteries** (after Masuhr and Neumann)
When the *arteria anterior, media* or *posterior cerebri* becomes occluded, characteristic functional deficits occur in the oxygen-deprived brain areas supplied by the occluded vessel. In many cases the affected artery can be identified based on the associated neurological deficit:

- Bladder weakness (cortical bladder center) and paralysis of the lower limb (hemiplegia with or without hemisensory deficit, predominantly affecting the leg) on the side opposite the occlusion indicate an infarction in the territory of the **arteria cerebri anterior**.
- Contralateral hemiplegia affecting the arm and face more than the leg indicates an infarction in the territory of the **arteria media cerebri**. If the dominant hemisphere is affected, aphasia also occurs (the patient cannot name objects, for example).
- Visual disturbances affecting the contralateral visual field (hemianopia) may signify an infarction in the territory of the **arteria posterior cerebri**, because the structures supplied by this artery include the visual cortex in the sulcus calcarinus of the lobus occipitalis. If branches to the thalamus are also affected, the patient may also exhibit a contralateral hemisensory deficit because the afferent sensory fibers have already crossed below the thalamus.

The extent of the infarction depends partly on whether the occlusion is proximal or distal. Generally a proximal occlusion will cause a much more extensive infarction than a distal occlusion. Infarctions of the arteria media cerebri are the most common because it is essentially a direct continuation of the arteria carotis interna.

Meninges

The brain (encephalon) and spinal cord (medulla spinalis) are covered by membranes called meninges. The meninges are composed of three layers: dura mater (dura), arachnoid (arachnoid membrane), and pia mater.

The spatium subarachnoideum, located between the arachnoid and pia, contains liquor cerebrospinalis (CSF, see **p. 94**). See **p. 74** for the coverings of the medulla spinalis.

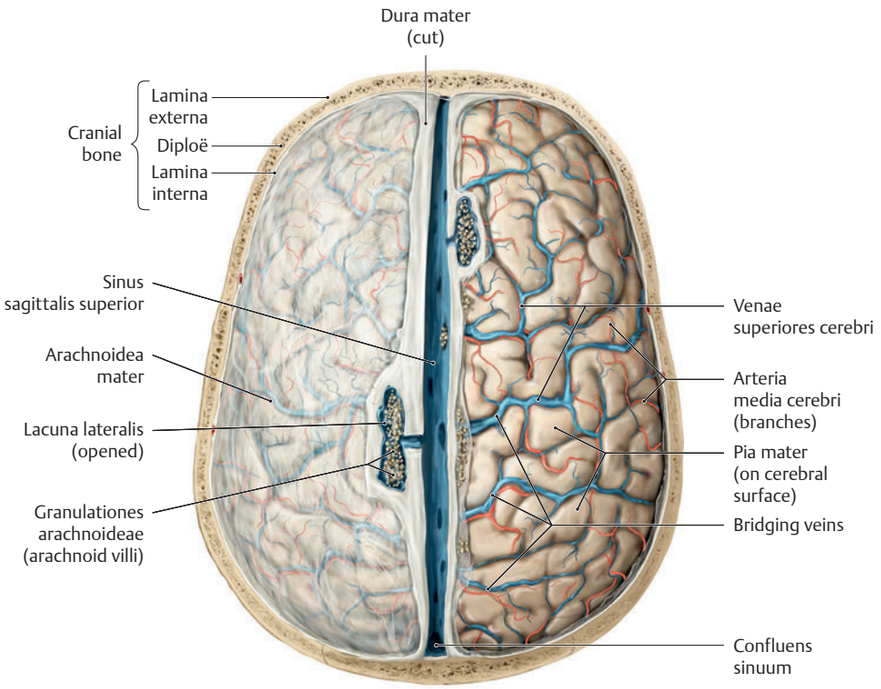


Fig. 4.56 **Layers of the Meninges**
Superior view of opened cranium. *Left side:* Dura mater (outer layer) cut to reveal arachnoidea mater (middle layer). *Right side:* Dura mater and arachnoidea mater removed to reveal pia mater (inner layer) lining the surface of the brain. *Note:* Granulationes arachnoideae, sites for loss of cliquor cerebrospinalis into the venous blood, are protrusions of the arachnoidea mater layer of the meninges into the venous sinus system.

Migraines are caused by the dilation of blood vessels in the pia mater and dura mater surrounding the encephalon which triggers the release of neuropeptides, e.g., substance P, from parasympathetic nerve fibers approximating these vessels and excites nociceptive fibers that travel in the nervus trigeminus (CN V) back to the brain. They are characterized by a severe, unilateral throbbing headache, which is often preceded by an aura (usually visual), and may be accompanied by nausea, vomiting, and photophobia (sensitivity to light).

Meningitis is inflammation of the meninges of the brain (pia mater and arachnoidea mater), usually due to a viral infection. Symptoms include headache, stiff neck, photophobia, irritability, drowsiness, vomiting, fever, seizures, and rash (viral or meningococcal meningitis).

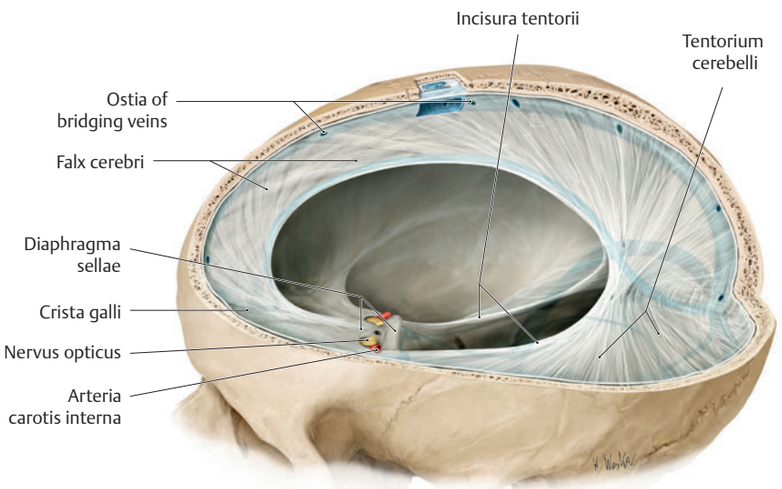


Fig. 4.57 **Dural septa (folds)**
Left anterior oblique view. Two layers of meningeal dura come together, after separating from the periosteal dura during formation of a dural (venous) sinus, to form a dural fold or septum. These include the falx cerebri (separating right and left cerebral hemispheres); the tentorium cerebelli (supporting the cerebrum to keep it from crushing the underlying cerebellum); the falx cerebelli (not shown, that separates right and left cerebellar lobes under the tentorium); and the diaphragma sellae (forms the roof over the fossa hypophysialis and is invaginated by the hypophysis).

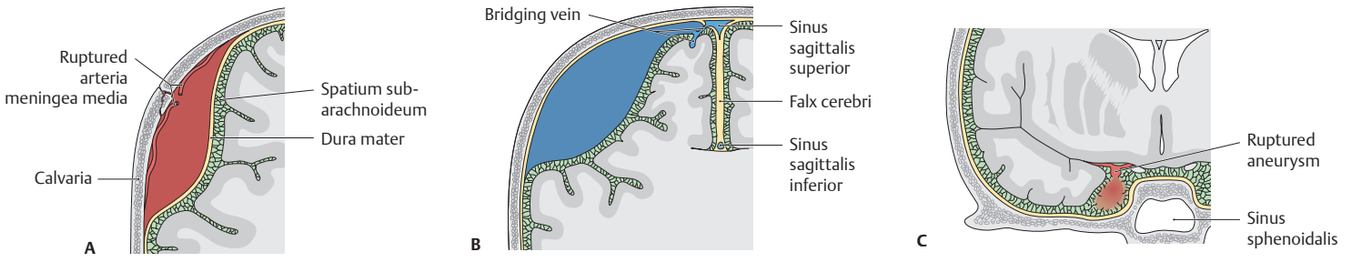


Fig. 4.58 **Extracerebral hemorrhages**
Bleeding between the bony calvarium and the soft tissues of the brain (extracerebral hemorrhage) exerts pressure on the brain. A rise of intracranial pressure may damage brain tissue both at the bleeding site and in more remote brain areas. Three types of extracranial hemorrhage are distinguished based on the relationship to the dura mater: (**A**) epidural hematoma, (**B**) subdural hematoma, or (**C**) subarachnoid hemorrhage. **A** Epidural hematomas generally develop after a head injury involving a skull fracture, causing rupture of the arteria meningea media. The hematoma forms between the calvaria and the periosteal layer of the dura mater. **B** Subdural hematomas usually form when trauma to the head causes the rupture of bridging veins. Bleeding occurs between the dura mater and the arachnoidea mater. Because the source of the bleeding is venous, a subdural hematoma may develop over a period of weeks. **C** Subarachnoid hemorrhage is an arterial bleed caused by the rupture of an aneurysm of an artery at the base of the brain (see **Fig 4.47**). It is typically caused by a brief, sudden rise in blood pressure, like that produced by a sudden rise in intra-abdominal pressure, e.g. straining at stool. Because the hemorrhage is into the CSF-filled spatium subarachnoideum, blood can be detected in the CSF by means of a lumbar puncture (see **Fig 4.9**).

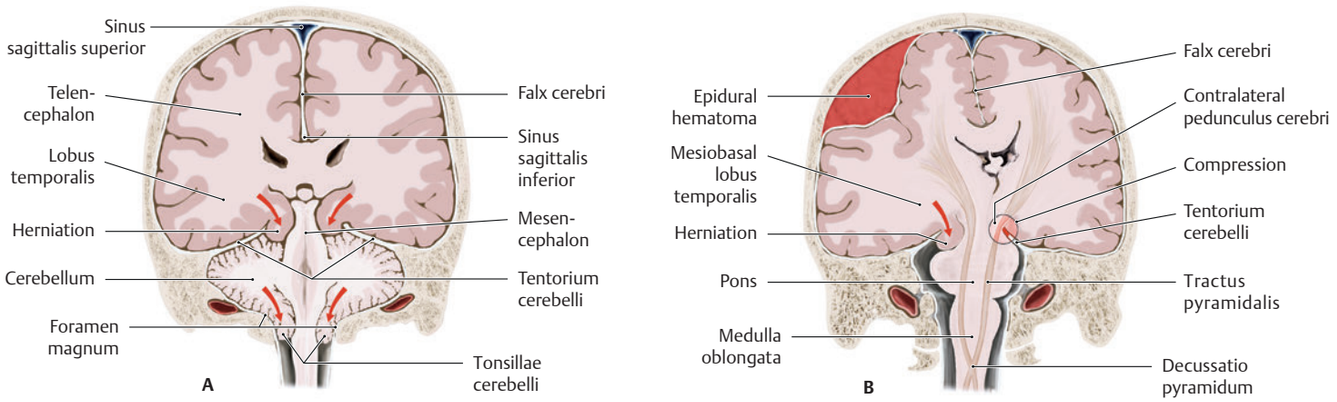


Fig. 4.59 **Potential sites of brain herniation beneath the free edges of the meninges**
Coronal section, anterior view. The tentorium cerebelli divides the cavitas cranii into a supratentorial and an infratentorial space. The telencephalon is supratentorial, and the cerebellum is infratentorial (**A**). Because the dura is composed of tough, collagenous connective tissue, it creates a rigid intracranial framework. As a result, a mass lesion within the cranium may displace the cerebral tissue and cause portions of the cerebrum to become entrapped (herniate) beneath the rigid dural septa (= duplication of the meningeal layer of the dura).
A Axial herniation. This type of herniation is usually caused by generalized brain edema. It is a symmetrical herniation in which the middle and lower portions of both temporal lobes of the cerebrum herniate down through the incisura tentorii, exerting pressure on the upper portion of the mesencephalon (bilateral uncal herniation). If the pressure persists, it will force the tonsillae cerebelli through the foramen magnum and also compress the lower part of the truncus encephali (tonsillar herniation). Because respiratory and circulatory centers are located in the truncus encephali, this type of herniation is life-threatening. Concomitant vascular compression may cause truncus encephali infarction.
B Lateral herniation. This type is caused by a unilateral mass effect (e.g., from a brain tumor or intracranial hematoma), as illustrated here on the right side. Compression of the ipsilateral pedunculus cerebri usually produces contralateral hemiparesis. Sometimes, the herniating mesiobasal portions of the lobus temporalis press the opposite pedunculus cerebri against the sharp edge of the tentorium. This damages the tractus pyramidalis above the level of its decussation, causing hemiparesis to develop on the side opposite the injury.

Sensory Pathways (Excluding the Head)

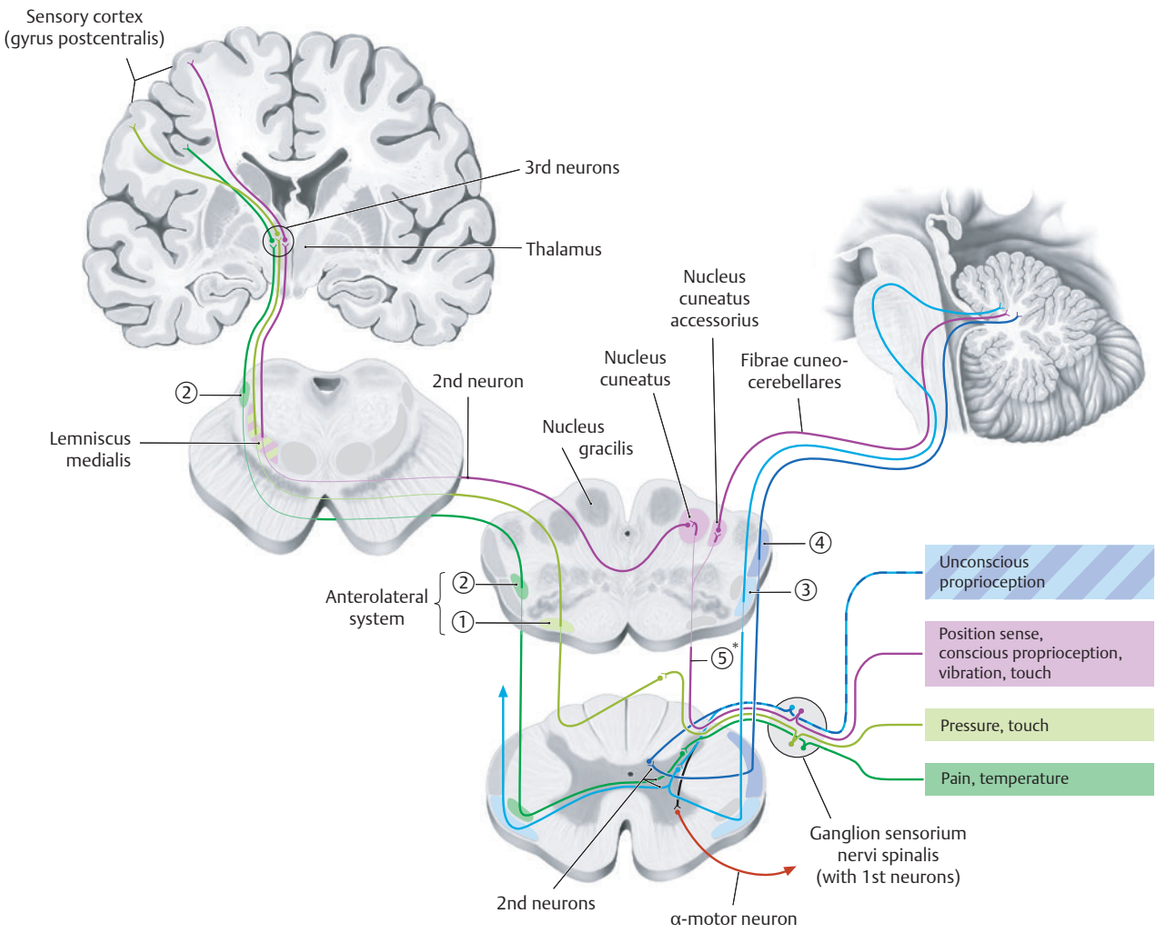


Fig. 4.60 **Sensory pathways (ascending tracts)**
Spinal nerve sensory pathways involve a three neuron chain: first-order, second-order, and third order. First-order sensory neurons, with cell bodies located outside the CNS, collect sensory data from the sensory organ and convey it to the CNS. The axons of first-order neurons enter the CNS, through the posterior (sensory) root and cornu posterius, to synapse on second-order sensory neurons. Second-order sensory neurons, located within the CNS, receive impulses from first-order neurons in the PNS. The axons of second-order neurons ascend as tracts to synapse on third-order sensory neurons located in the thalamus; some second-order neurons project to the cerebellum via the tractus spinocerebellares and fibrae cuneocerebellares. Third-order sensory neurons project axons to the sensory cortex. See **Table 4.7** for more details.

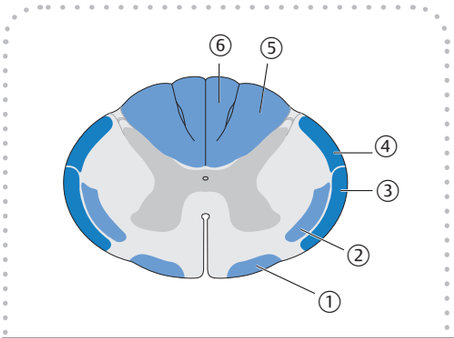


Table 4.7 **Ascending tracts of the medulla spinalis**

Tract		Location	Function		Neurons
①	Tractus spinothalamicus anterior	Funiculus anterior	Pathway for crude touch and pressure sensation		1st order afferent neurons located in ganglia sensoria nervorum spinalium; contain 2nd order neurons and cross in the commissura anterior
②	Tractus spinothalamicus lateralis	Funiculi anterior and laterais	Pathway for pain, temperature, tickle, itch, and sexual sensation		
③	Tractus spinocerebellaris anterior	Funiculus lateralis	Pathway for unconscious coordination of motor activities (unconscious proprioception, automatic processes, e.g., jogging, riding a bike) to the cerebellum		Projection (2nd order) neurons receive proprioceptive signals from 1st order afferent fibers originating at the 1st order neurons of ganglia sensoria nervorum spinalium
④	Tractus spinocerebellaris posterior				
⑤	Fasciculus cuneatus	Funiculus posterior	Pathway for position sense (conscious proprioception) and fine cutaneous sensation (touch, vibration, fine pressure sense, two-point discrimination)	Conveys information from *upper* limb (not present below T3)	Cell bodies of 1st order neurons located in ganglion sensorium nervi spinalis; pass uncrossed to the columna posterior nuclei
⑥	Fasciculus gracilis*			Conveys information from *lower* limb	

* The fasciculi cuneatus and gracilis convey information from the upper and lower limbs, respectively. At this medulla spinalis level, only the fasciculus cuneatus is present.

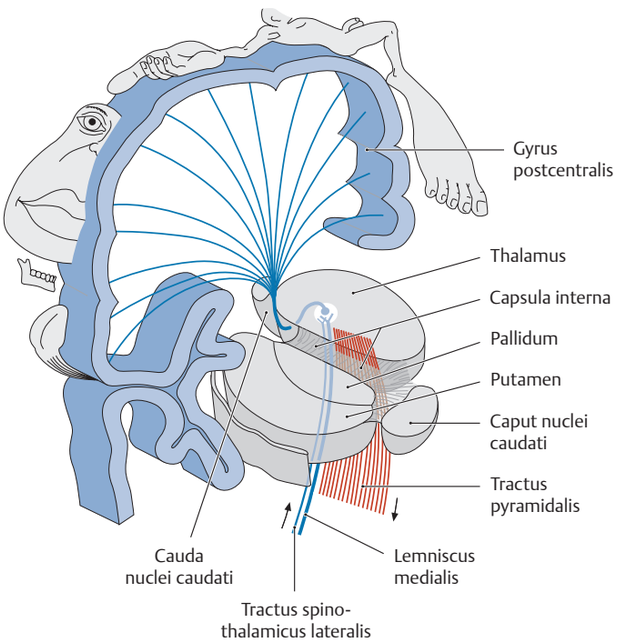


Fig. 4.61 **Arrangement of sensory pathways in the cerebrum**
Anterior view of the right gyrus postcentralis. The cell bodies of the third order neurons of the sensory pathways are located in the thalamus. Their axons project to the gyrus postcentralis, where the primary somatosensory cortex is located. The gyrus postcentralis has a somatotopic organization, meaning that each body region is represented in a particular cortical area. The body regions in the cortex are not represented in proportion to their actual size, but in proportion to the density of their sensory innervation. The fingers and head have abundant sensory receptors, and so their cortical representation is correspondingly large. Conversely, the less dense sensory innervation of the buttocks and legs results in smaller areas of representation. Based on these varying numbers of peripheral receptors, we can construct a "sensory homunculus" whose parts correspond to the cortical areas concerned with their perception.
Note: The head of the homunculus is upright while the trunk is upside down.
The axons of the sensory neurons ascending from the thalamus travel side by side with the axons forming the tractus pyramidalis (red) in the posterior part of the capsula interna. Because of this arrangement, a large cerebral hemorrhage involving the capsula interna produces sensory as well as motor deficits (see Kell et al.).

Sensory Pathways: Pain Pathways in the Head & the Central Analgesic System

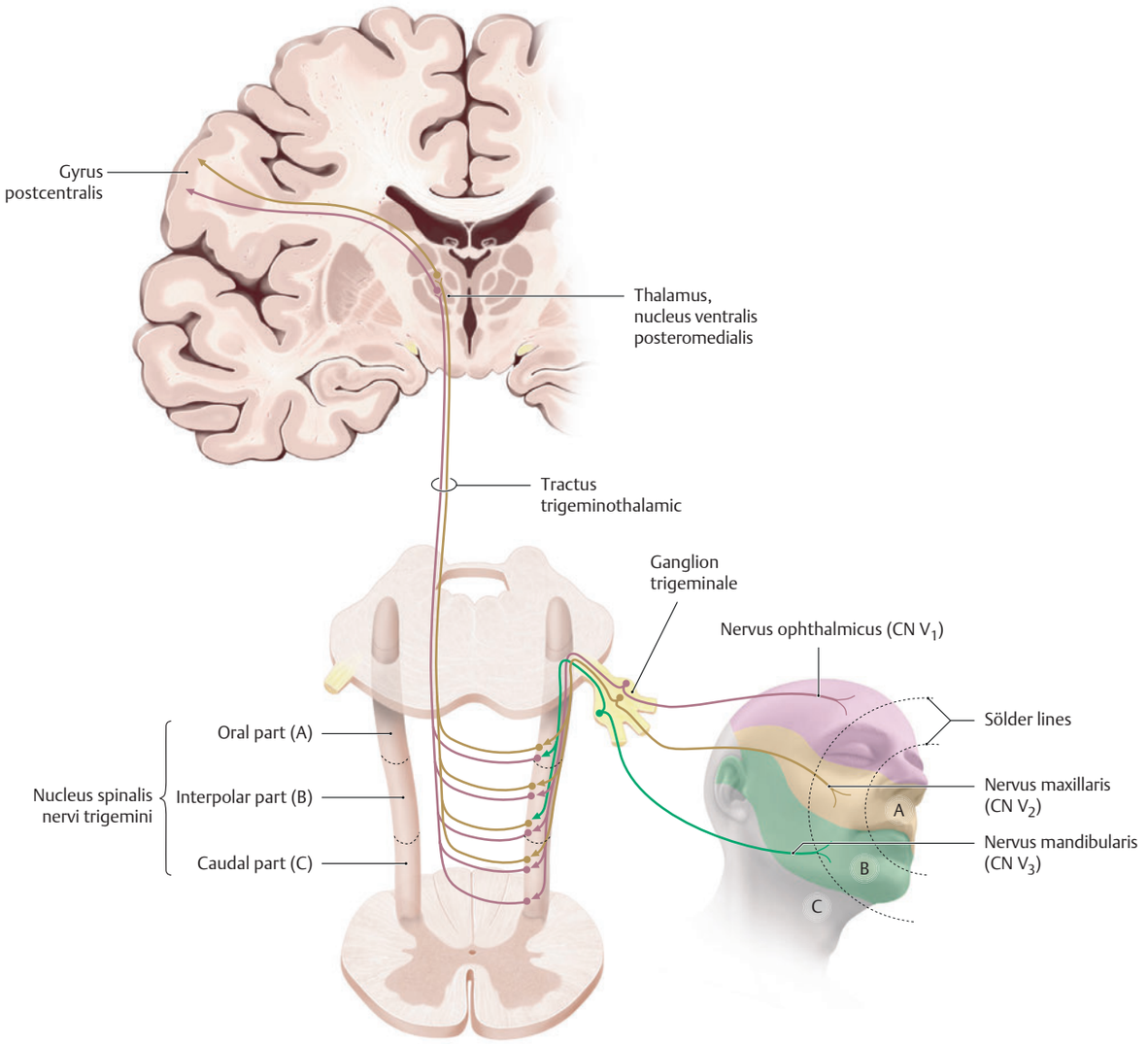


Fig. 4.62 **Pain pathways in the head** (after Lorke)
The pain fibers in the head accompany the principal divisions of the nervus trigeminus (CN V_1–V_3). The cell bodies of these first order afferent neurons of the pain pathway are located in the ganglion trigeminale. Their axons terminate in the nucleus spinalis nervi trigemini.
Note the somatotopic organization of this nuclear region: The perioral region (**A**) is cranial and the occipital regions (**C**) are caudal. Because of this arrangement, central lesions lead to deficits that are distributed along the Sölder lines.
The axons of the second order neurons cross the midline and travel in the tractus trigeminothalamicus to the nucleus ventralis posteromedialis and to the nuclei intralaminares thalami on the opposite side, where they terminate. The third order (thalamic) neuron of the pain pathway ends in the primary somatosensory cortex. Only the pain fibers of the nervus trigeminus are pictured in the diagram. In the nervus trigeminus itself, the other sensory fibers run parallel to the pain fibers but terminate in various trigeminal nuclei.
Oral dysaesthesia, or *burning mouth syndrome*, is a debilitating, intractable, burning sensation of the oral mucosa that is present without evidence of clinical disease. The precise cause of oral dysaesthesia is unknown but derangements in central and peripheral pain pathways have been implicated and it is also thought to have a strong psychogenic component. It is many times more common in women and tends to affect those in the 40–50 years age range, many of whom are suffering from depression. Diagnosis is made by exclusion of all organic and prosthetic causes. Treatment is usually with antidepressant drugs, which both treat any precipitating or coexisting depression, and affect central pain pathways.

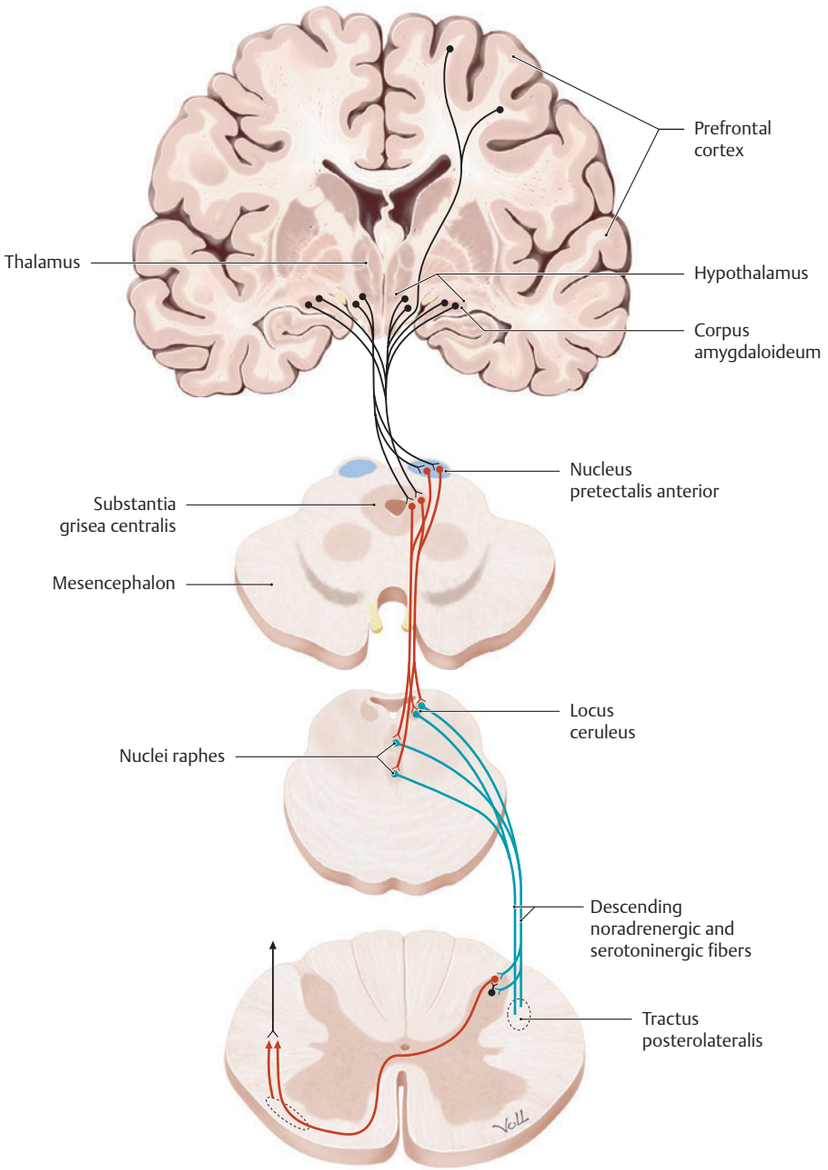


Fig. 4.63 **Pathways of the central descending analgesic system** (after Lorke)

Besides the ascending pathways that carry pain sensation to the primary somatosensory cortex, there are also descending pathways that have the ability to suppress pain impulses. The central relay station for the descending analgesic (pain-relieving) system is the substantia grisea centralis of the mesencephalon. It is activated by afferent input from the hypothalamus, the prefrontal cortex, and the corpora amygdaloidea (part of the limbic system, not shown). It also receives afferent input from the medulla spinalis. The axons from the excitatory glutaminergic neurons (red) of the central gray matter terminate on serotoninergic neurons in the nuclei raphes and on noradrenergic neurons in the locus caeruleus (both shown in blue). The axons from both types of neuron descend in the tractus posterolateralis. They terminate directly or indirectly (via inhibitory neurons) on the analgesic projection neurons (second order afferent neuron of the pain pathway), thereby inhibiting the further conduction of pain impulses.

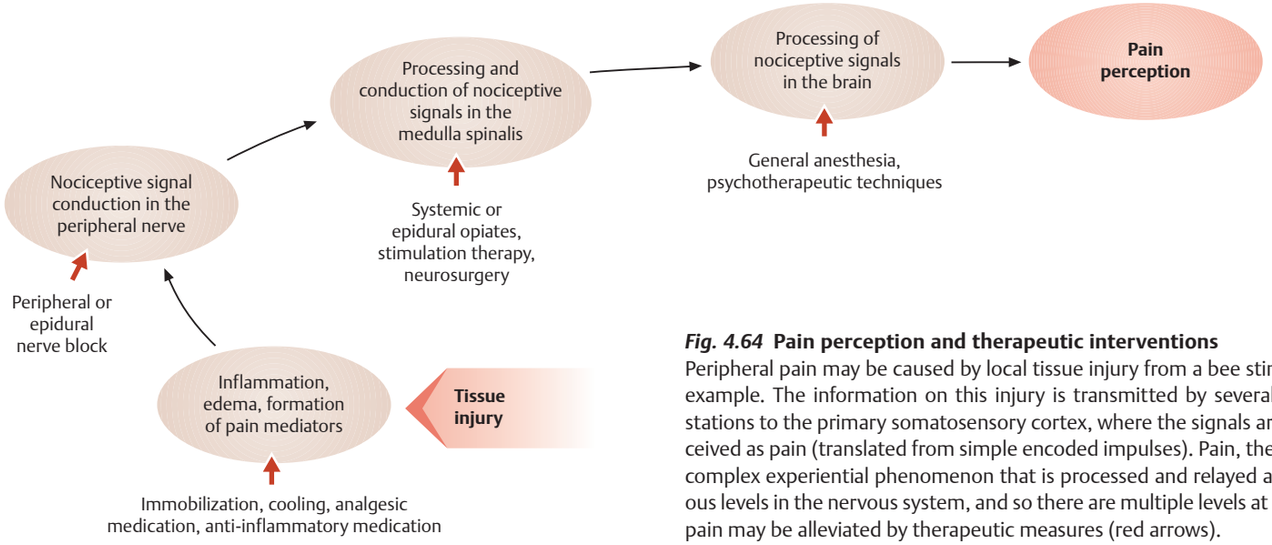
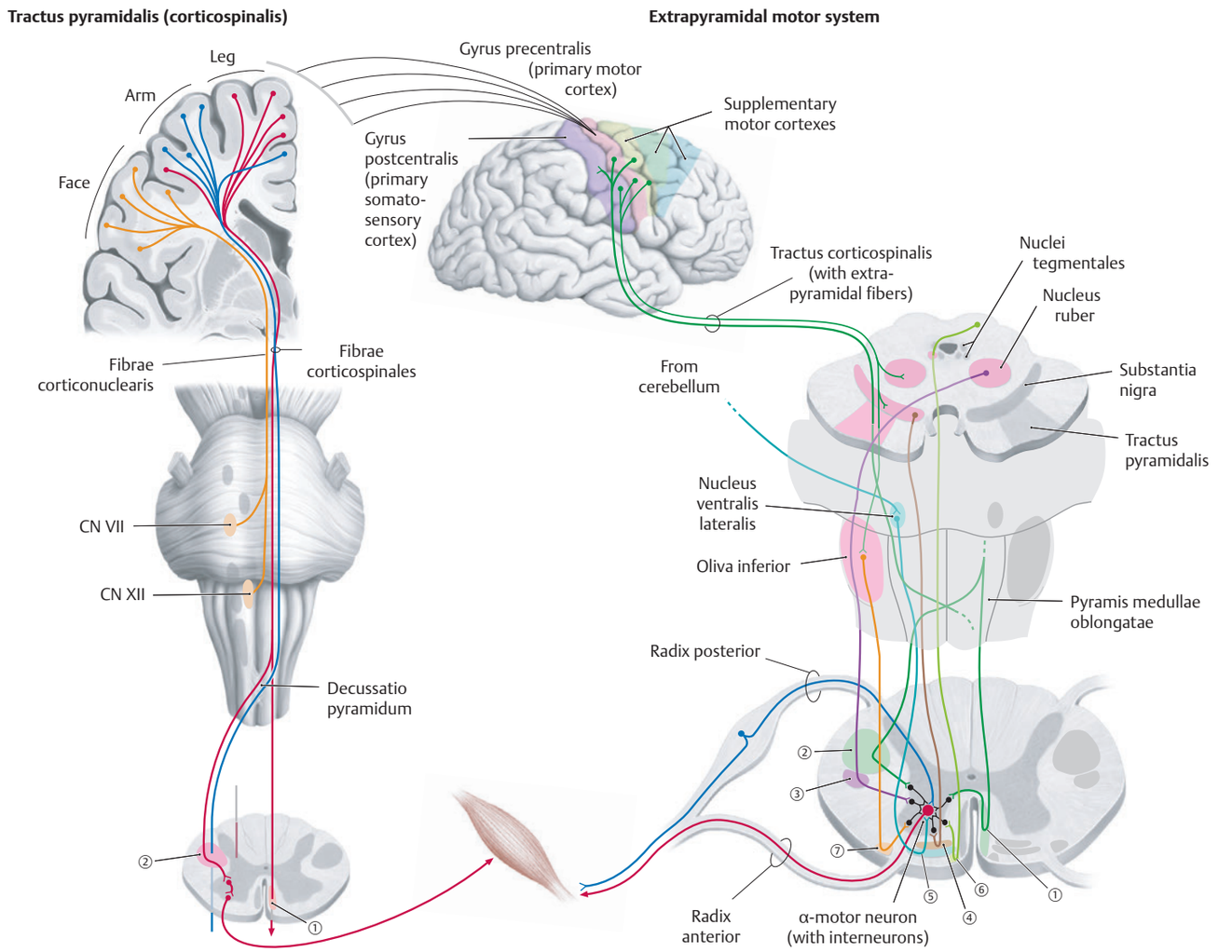


Fig. 4.64 **Pain perception and therapeutic interventions**

Peripheral pain may be caused by local tissue injury from a bee sting, for example. The information on this injury is transmitted by several relay stations to the primary somatosensory cortex, where the signals are perceived as pain (translated from simple encoded impulses). Pain, then, is a complex experiential phenomenon that is processed and relayed at various levels in the nervous system, and so there are multiple levels at which pain may be alleviated by therapeutic measures (red arrows).

Motor Pathways



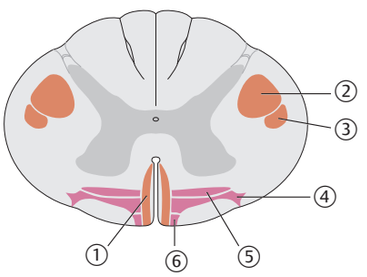


Table 4.8 **Descending tracts of the medulla spinalis**

Tract			Function	
Tractus pyramidalis	①	Tractus corticospinalis anterior	Most important pathway for voluntary motor function is the gyrus cinguli (limbic system)	Originates in the motor cortex fibrae *corticonucleares* to motor nuclei of nervi craniales Fibrae *corticospinales* to motor cells in anterior horn of the medulla spinalis Fibrae *corticoreticulares* to nuclei of the formatio reticularis
	②	Tractus corticospinalis lateralis		
Extrapyramidal motor system	③	Tractus rubrospinalis	Pathway for automatic and learned motor processes (e.g., walking, running, cycling)	
	④	Tractus reticulospinalis		
	⑤	Tractus vestibulospinalis		
	⑥	Tractus tectospinalis		
	⑦	Fibrae olivospinales		

Fig. 4.65 **Motor pathways (descending tracts)**
The motor pathway for the innervation of skeletal muscle involves two neurons, an upper motor neuron and a lower motor neuron. The cell bodies of the upper motor neurons, which are associated with both nervi craniales and nervi spinales, are located in the substantia grisea of the gyrus precentralis of the cortex cerebri. The axons of the upper motor neurons descend via white matter tracts to reach the lower motor neurons, which are located in motor nuclei of the truncus encephali and in the cornu anterius of the medulla spinalis. The majority of upper motor neurons descending in the tractus corticospinalis cross to the contralateral side at the decussatio pyramidum at the spinomedulary junction. The cornu anterius is the anterior portion of the substantia grisea of the medulla spinalis, containing exclusively motor neurons. The axons of these neurons leave the CNS as the radix anterior (motoria) of the nervi spinales to synapse on target cells. The radix anterior (motoria) combines with the radix posterior (sensoria), in the foramen intervertebrale, to form a mixed nervus spinalis. Lower motor neurons in the motor nuclei of the truncus encephali (nervi craniales) project axons that emerge from the CNS as the radices motoriae of nervi craniales. See **Table 4.8** for more details.

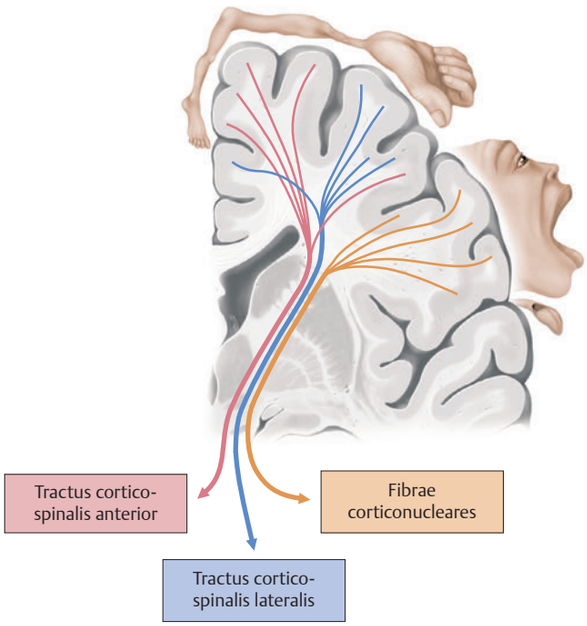


Fig. 4.66 **Somatotopic representation of the skeletal muscle in the gyrus precentralis (motor homunculus)**
Anterior view. Regions in which the muscles are very densely innervated (e.g., the hand) must be supplied by many neurons in the gyrus precentralis. As a result, they require a larger representation area in the cortex than regions supplied by fewer neurons (e.g., the trunk). This cortical representation is analogous to that in sensory innervation, where areas of varying size are also represented in the cortex (gyrus postcentralis; compare with the sensory homunculus in **Fig 4.61**). One cortical area is devoted to the trunk and limbs and another to the head. The axons for the head area are the fibrae corticonucleares, and the axons for the trunk and limbs are the fibrae corticospinales. The latter fibers split into two groups below the telencephalon, forming the tractus corticospinales laterales and anteriores.

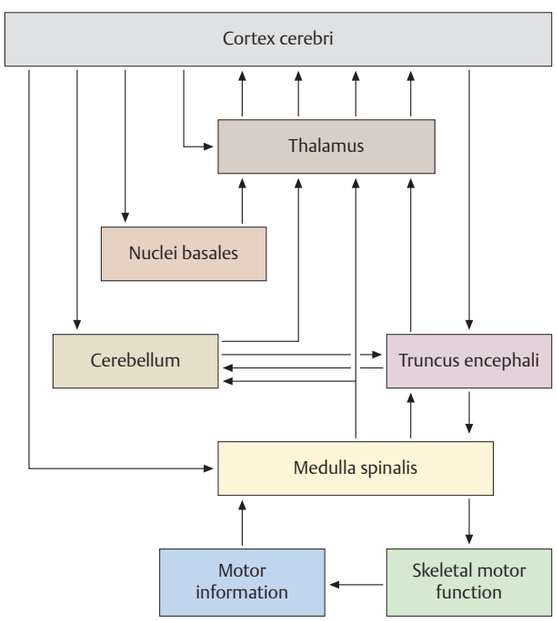


Fig. 4.67 **Simplified diagram of the sensorimotor system role in movement control**
Voluntary movements require constant feedback from the periphery (muscle spindles, Golgi tendon organs) in order to remain within the desired limits. Because the motor and sensory systems are so closely interrelated functionally, they are often described jointly as the sensorimotor system. The medulla spinalis, truncus encephali, cerebellum, and cortex cerebri are the three control levels of the sensorimotor system. All information from periphery, cerebellum, and the nuclei basales passes through the thalamus on its way to the cortex cerebri. The clinical importance of the sensory system in movement is seen in sensory ataxia (loss of coordination) which may occur when sensory input into the control of movement is lost. The oculomotor component of the sensorimotor system is not shown.

Autonomic Nervous System (I): Overview

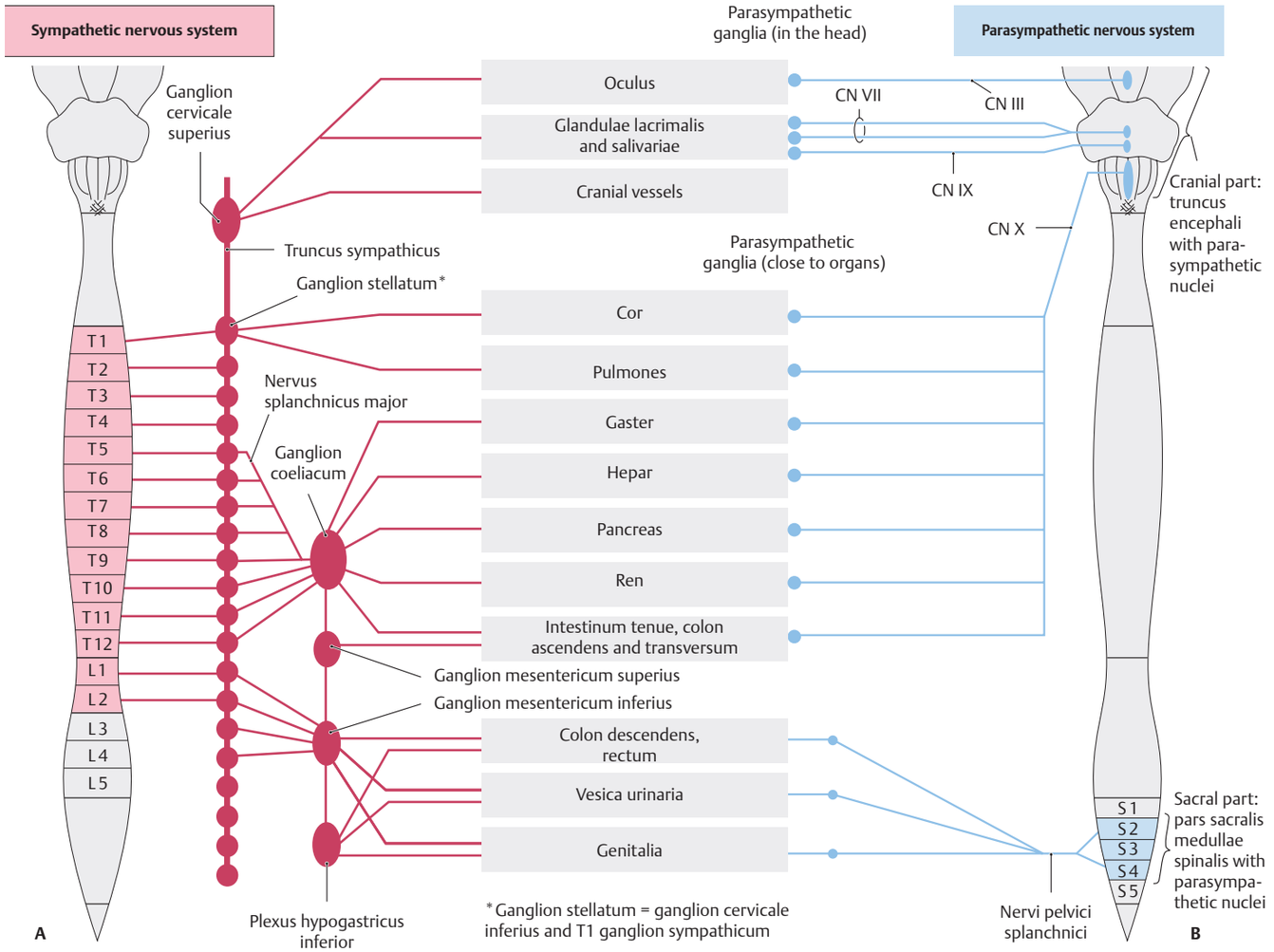


Fig. 4.68 **Autonomic nervous system**

The autonomic nervous system is the part of the peripheral nervous system that innervates smooth muscle, cardiac muscle, and glandulae. It is subdivided into the sympathetic (red) and the parasympathetic (blue) nervous systems, which often act in antagonistic fashion to regulate blood flow, secretions, and organ function.

Both the sympathetic and parasympathetic nervous systems have a two-neuron pathway, which is under central nervous system control via an upper motor neuron with its cell body in the hypothalamus.

In the sympathetic system, the preganglionic neuron synapses within the ganglia of the truncus sympathicus (paired, one on each side of columna vertebralis) or on one of the unpaired prevertebral ganglia located at the base of the artery for which the ganglion was named (coeliaca, mesenterica superior and inferior). Sympathetic postganglionic neurons then either re-enter nervi spinales via rami communicantes grisei and are distributed to their target structure or they reach their target structure by travelling with arteries. Except in the head, parasympathetic preganglionic neurons synapse in ganglia in the wall of the target organ. Short postganglioinc parasympathetic neurons then innervate the organ. In the head there are four parasympathetic ganglia: ganglion ciliare, ganglion pterygopalatinum, ganglion submandibulare, ganglion oticum, which are associated with nervi craniales III, VII, and IX, respectively. These four ganglia are responsible for distributing fibers to smooth muscle within the eye and to the glandulae salivariae and glandulae cavitatis nasi, sinus paranasales, palatum durum and molle, and pharynx.

Both sympathetic and parasympathetic preganglionic neurons secrete acetylcholine, which acts upon nicotinic receptors in the ganglia. Sympathetic postganglionic neurons secrete norepinephrine, which acts upon adrenoceptors (α or β) in target tissues. Parasympathetic postganglionic neurons secrete acetylcholine, which acts upon muscarinic receptors in target tissues.

Table 4.9 Parasympathetic pathways

Neuron	Location of cell body (soma)	
Upper motor neuron	**Hypothalamus:** The cell bodies of parasympathetic upper motor neurons are located in the hypothalamus. Their axons descend via white matter tracts to synapse with the lower motor neuron in the truncus encephali and sacral medulla spinalis (S2–S4).	
Preganglionic neuron (lower motor neuron)	The parasympathetic nervous system is divided into two parts (cranial and sacral), based on the location of the preganglionic parasympathetic neurons.	
	Truncus encephali, nuclei nervorum cranialium: The axons of these secondary neurons leave the CNS as the radix motorius of nervi craniales III, VII, IX, and X.	**Medulla spinalis (S2–S4):** The axons of these secondary neurons leave the CNS (S2–S4) as the nervi splanchnici pelvici. These nerves travel in the rami posteriores of the S2–S4 nervi spinales and are distributed via the sympathetic plexuses to the pelvic viscera.
Postganglionic neuron	**Ganglia parasympathica nervorum cranialium:** The nervi craniales parasympathici of the head each have at least one ganglion: • CN III: Ganglion ciliare • CN VII: Ganglia pterygopalatinum and submandibulare • CN IX: Ganglion oticum • CN X: Small unnamed ganglia close to target structures	
Distribution of postganglionic fibers	Parasympathetic fibers course with other fiber types to their targets. In the head, the postganglionic fibers from the ganglion pterygopalatinum (CN VII) and ganglion oticum (CN IX) are distributed via branches of the nervus trigeminus (CN V). Postganglionic fibers from the ganglion ciliare (CN III) course with sympathetic and sensory fibers in the nervi ciliares breves (preganglionic fibers travel with the somatomotor fibers of CN III). In the thorax, abdomen, and pelvis, preganglionic parasympathetic fibers from CN X and the nervi splanchnici pelvici combine with postganglionic sympathetic fibers to form plexuses (e.g., cardiacus, pulmonalis, oesophageus).	

Table 4.10 Sympathetic pathways

Neuron	Location of cell body (soma)	
Upper motor neuron	**Hypothalamus:** The cell bodies of parasympathetic upper motor neurons are located in the hypothalamus. Their axons descend via white matter tracts to synapse with the lower motor neuron in the cornu laterale of the medulla spinalis (T1–L2).	
Preganglionic neuron (lower motor neuron)	**Cornu laterale of medulla spinalis (T1–L2):** The cornu laterale is the middle portion of the substantia grisea of the medulla spinalis, situated between the cornua anterius and posterius. It contains exclusively autonomic (sympathetic) neurons. The axons of these neurons leave the CNS as the radix motorius of the nervi spinales and enter the paravertebral ganglia via the rami communicantes albi (myelinated).	
Preganglionic neurons in paravertebral ganglia	All preganglionic sympathetic neurons enter the sympathetic chain. There they may synapse in a chain ganglion or ascend or descend to synapse. Preganglionic sympathetic neurons synapse in one of two places, yielding two types of sympathetic ganglia.	
	Synapse *in* the paravertebral ganglia	Pass without synapsing *through* the parasympathetic ganglia. These fibers travel in the nervi splanchnici major, lumbalis, and sacrais to synapse in the prevertebral ganglia.
Postganglionic neuron	**Paravertebral ganglia:** These ganglia form the trunci sympathici that flank the medulla spinalis. Postganglionic axons leave the truncus sympathicus via the gray rami communicantes (unmyelinated).	**Prevertebral ganglia:** Associated with peripheral plexuses, which spread along the aorta abdominalis. There are three primary prevertebral ganglia: • Ganglion coeliacum • Ganglion mesentericum superius • Ganglion mesentericum inferius
Distribution of postganglionic fibers	Postganglionic fibers are distributed in two ways: 1. Nervi spinales: Postganglionic neurons may re-enter the nervi spinales via the rami communicantes grisei. These sympathetic neurons induce constriction of blood vessels, glandulae sudoriferae, and musculi arrectores (muscle fibers attached to hair follicles, “goose bumps”). 2. Arteriae and ducts: Nerve plexuses may form along existing structures. Postganglionic sympathetic fibers may travel with arteries to target structures. Viscera are innervated by this method (e.g., sympathetic innervation concerning vasoconstriction, bronchial dilatation, glandular secretions, pupillary dilatation, smooth muscle contraction).	

Autonomic Nervous System (II): Connections

Fig. 4.69 **Parasympathetic nervous system (cranial part): Overview**

There are four parasympathetic nuclei in the truncus encephali. The visceral efferent fibers of these nuclei travel along particular nervi craniales, listed below.

- Nucleus visceralis (Edinger–Westphal nucleus): nervus oculomotorius (CN III)
- Nucleus salivatorius superior: nervus facialis (CN VII)
- Nucleus salivatorius inferior: nervus glossopharyngeus (CN IX)
- Nucleus posterior nervi vagi: nervus vagus (CN X)

The presynaptic parasympathetic fibers often travel with multiple nervi craniales to reach their target organs. The nervus vagus supplies all of the thoracic and abdominal organs as far as a point near the left colic flexure.
Note: The sympathetic fibers to the head travel along the arteries to their target organs.

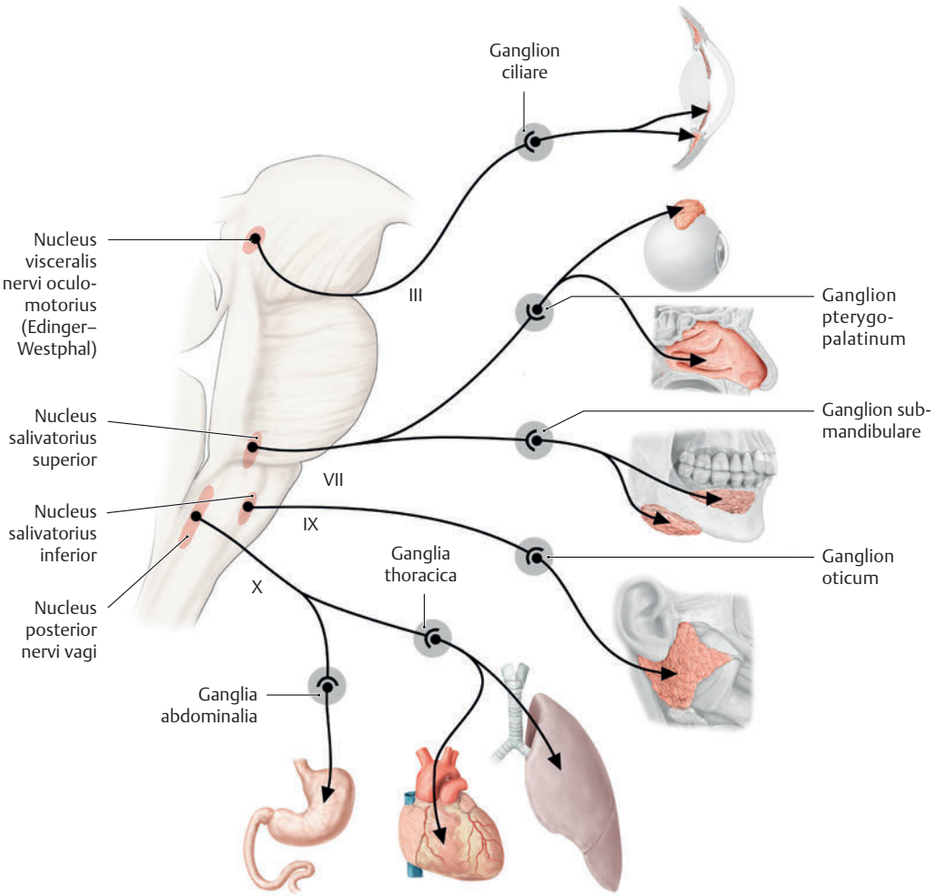


Table 4.11 **Parasympathetic ganglia in the head**

Nucleus	Path of presynaptic fibers	Ganglion	Postsynaptic fibers	Target organs
Nucleus visceralis nervi oculomotorii	Nervus oculomotorius (CN III)	Ganglion ciliare	Nervi ciliares breves (CN V_1)	Musculus ciliaris (accommodation) Musculus sphincter pupillae (miosis)
Nucleus salivatorius superior	Nervus intermedius (CN VII root) →nervus petrosus major→nervus canalis pterygoidei	Ganglion pterygopalatinum	• Nervus maxillaris (CN V_2) →nervus zygomaticus →anostomosis→nervus lacrimalis (CN V_1) • Rami orbitales • Rami nasales posteriores superiores • Nervus nasopalatinus • Nervi palatini major and minores	• Glandula lacrimalis • Glandulae cavitatis nasi and sinus paranasales • Glandulae gingivae • Glandulae palati duri and mollis • Glandulae pharyngis
	Nervus intermedius (CN VII root) →chorda tympani →nervus lingualis (CN V_3)	Ganglion submandibulare	Rami glandulares	Glandula submandibularis Glandula sublingualis
Nucleus salivatorius inferior	Nervus glossopharyngeus (CN IX) →nervus tympanicus →nervus petrosus minor	Ganglion oticum	Nervus auriculotemporalis (CN V_3)	Glandula parotidea
Nucleus posterior nervi vagi	Nervus vagus (CN X)	Ganglia near organs	Fine fibers in organs, not individually named	Thoracic and abdominal viscera

→ = is continuous with

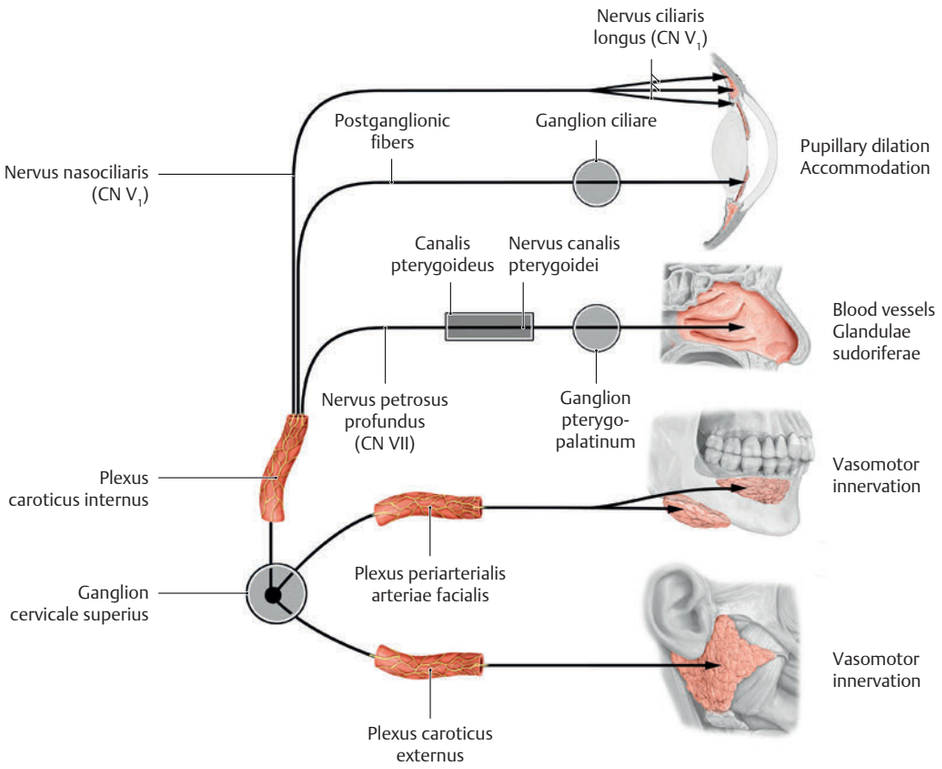


***Fig. 4.70* Sympathetic innervation of the head**

Sympathetic preganglionic neurons of the head originate in the cornu laterale of the medulla spinalis (TI–L2). They exit into the sympathetic chain ganglia and ascend to synapse in the ganglion cervicale superius. Postganglionic neurons then travel with nerve plexuses along arteries. Postganglionic fibers that travel with the plexus caroticus internus join with the nervus nasociliaris (of CN V_1) and then the nervi ciliares longi to reach the musculus dilatator pupillae (pupillary dilation); other postganglionic fibers travel through the ganglion ciliare (without synapsing) to reach the musculus ciliaris (accommodation). Still other postganglionic fibers from the plexus caroticus internus leave with the nervus petrosus profundus, which joins with the nervus petrosus major (CN VII), to form the nervus canalis pterygoidei (vidian nerve). This nerve travels to the ganglion pterygopalatinum where it distributes fibers via branches of the nervus maxillaris to the glandulae cavitatis nasi, sinus maxillaris, palatum durum and molle, gingiva, and pharynx, and to glandulae sudoriferae and blood vessels in the head.

Postganglionic fibers from the ganglion cervicale superius that travel with the Plexus periarterialis arteriae facialis pass through the ganglion submandibulare (without synapsing) to the glandulae submandibularis and sublingualis. Other postganglionic fibers travel with the middle meningeal plexus, through the ganglion oticum (without synapsing), to the glandula parotidea.

***Table 4.12* Sympathetic fibers in the head**

Nucleus	Path of presynaptic fibers	Ganglion	Postsynaptic fibers	Target organs
Cornu laterale medullae spinalis (TI–L2)	Enter sympathetic chain ganglia and ascend to ganglion cervicale superius	Ganglion cervicale superius	Plexus caroticus internus→nervi nasociliares (CN V_1)→long ciliary nn. (CN V_1)	Musculus dilatator pupillae (mydriasis)
			Postganglionic fibers→ganglion cervicale*→nervi ciliares breves	Musculus ciliaris (accommodation)
			Plexus caroticus internus→nervus petrosus profundus→nervus canalis pterygoidei →ganglion pterygopalatinum* →branches of nervus maxillaris (CN V_2)	Glandulae cavitatis nasi Glandulae sudoriferae Blood vessels
			Plexus periarterialis arteriae facialis→ganglion submandibulare*	Glandula submandibularis Glandula sublingualis
			External carotid artery plexus	Glandula parotidea

*passes through without synapsing; → = is continuous with

Nervi Craniales: Overview

Table 4.13 Nervi craniales

Nervus cranialis	Attachment to brain	Fiber type (Table 4.11)						
		Afferent				Efferent		
CN I: Nervus olfactorius	Telencephalon			●				
CN II: Nervus opticus	Diencephalon	●						
CN III: Nervus oculomotorius	Mesencephalon					●	●	
CN IV: Nervus trochlearis						●		
CN V: Nervus trigeminus	Pons		●					●
CN VI: Nervus abducens	Pontomedullary junction					●		
CN VII: Nervus facialis			●	●			●	●
CN VIII: Nervus vestibulocochlearis		●						
CN IX: Nervus glossopharyngeus	Medulla oblongata		●	●	●		●	●
CN X: Nervus vagus			●	●	●		●	●
CN XI: Nervus accessorius						●		●
CN XII: Nervus hypoglossus						●		

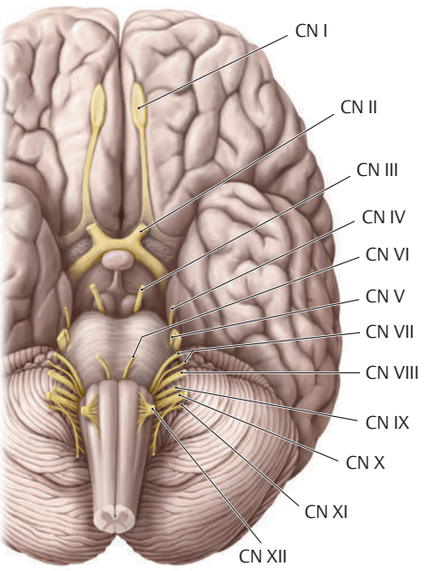


***Fig. 4.71* Nervi craniales**
Whereas the 31 spinal nerve pairs emerge from the medulla spinalis, the 12 pairs of nervi craniales emerge from the brain at various levels (**Table 4.13**). They are numbered according to the order of their emergence. (*Note:* Nervi craniales I and II are not true peripheral nerves but are instead extensions of the telencephalon [CN I] and diencephalon [CN II].) Unlike the nervi spinales, which each have a radix sensoria posterior and a radix motoria anterior, the nervi craniales may contain afferent (sensory) and/or efferent (motor) fibers. The types of fibers (**Table 4.14**) correspond to the function of the nerve (**Table 4.15**).

Table 4.14 Cranial nerve fiber types

The seven types of cranial nerve fibers are classified according to three criteria (reflected in the three-letter codes): 1. General (G) vs. Special (S), 2. Somatic (S) vs. Visceral (V), 3. Afferent (A) vs. Efferent (E). Each fiber type has an associated color used throughout this chapter.

	Afferent (sensory) fibers			Efferent (motor) fibers		
General fibers	GSA	General somatosensory	General sensation (touch, pain, and temperature) from somitus derivatives (skin, skeletal muscle, and mucosa)	GSE	Somatomotor	Motor innervation to striated (skeletal) muscle derived from somiti
	GVA	General viscerosensory	General sensation from viscera (smooth muscle, cardiac muscle, and glandulae)	GVE	Parasympathetic	Motor innervation to viscera (smooth muscle, cardiac muscle, glandulae, etc.)
Special fibers	SSA	Special somatosensory	Sight, hearing, and balance			
	SVA	Special viscerosensory	Taste and smell	SVE	Branchiomotor	Fibers to striated (skeletal) muscle derived from the branchial arches

Table 4.15 **Cranial nerve function**

Nervus cranialis		Passage through skull	Fiber		Sensory territory (afferent) / Target organ (efferent)
			A	E	
CN I: Nervus olfactorius (p. 118)		Os ethmoidale (lamina cribrosa)	●		Smell: special viscerosensory fibers from olfactory mucosa of cavitas nasi
CN II: Nervus opticus (p. 119)		Canalis opticus	●		Sight: special somatosensory fibers from retina
CN III: Nervus oculomotorius (pp. 120–121)		Fissura orbitalis superior		●	Somatomotor innervation: to musculus levator palpebrae superioris and four extraocular musculi (musculi recti superior, medialis, and inferior, and musculus obliquus inferior)
				●	Parasympathetic innervation: preganglionic fibers to ganglion ciliare; postganglionic fibers to intraocular musculi (musculi ciliares and sphincter pupillae)
CN IV: Nervus trochlearis (pp. 120–121)		Fissura orbitalis superior		●	Somatomotor innervation: to one extraocular musculus (musculus obliquus superior)
CN V: Nervus trigeminus (pp. 122–129)	CN V_1 (pp. 124–125)	Fissura orbitalis superior	●		General somatic sensation: from orbita, cavitas nasi, sinus paranasales, and face
	CN V_2 (pp. 126–127)	Foramen rotundum	●		General somatic sensation: from cavitas nasi, sinus paranasales, superior pars nasalis pharyngis, upper cavitas oris, internal skull, and face
	CN V_3 (pp. 128–129)	Foramen ovale	●		General somatic sensation: from lower cavitas oris, auris, internal skull, and face
				●	Branchiomotor innervation: to the eight musculi derived from the 1st arcus pharyngeus (including mm. of mastication)
CN VI: Nervus abducens (pp. 120–121)		Fissura orbitalis superior		●	Somatomotor innervation: to one extraocular m. (musculus rectus lateralis)
CN VII: Nervus facialis (pp. 130–133)		Meatus acusticus internus	●		General somatic sensation: from auris externa
			●		Taste: special viscerosensory fibers from tongue (anterior ⅔) and palatum molle
				●	Parasympathetic innervation: preganglionic fibers to ganglia submandibulare and pterygopalatinum; postganglionic fibers to glandulae (e.g., lacrimalis, submandibularis, sublingualis, palatinum) and mucosa of cavitas nasi, palatum, and sinus paranasales
				●	Branchiomotor innervation: to mm. derived from the 2nd arcus pharyngeus (including musculi faciei, musculus stylohyoideus, and musculus stapedius)
CN VIII: Nervus vestibulocochlearis (pp. 134–135)		Meatus acusticus internus	●		Hearing and balance: special somatosensory fibers from cochlea (hearing) and vestibular apparatus (balance)
CN IX: Nervus glossopharyngeus (pp. 136–137)		Foramen jugulare	●		General somatic sensation: from cavitas oris, pharynx, tongue (posterior ⅓), and auris media
			●		Taste: special visceral sensation from tongue (posterior ⅓)
			●		General visceral sensation: from glomus caroticum and sinus caroticus
				●	Parasympathetic innervation: preganglionic fibers to ganglion oticum; postganglionic fibers to glandula parotidea and glandulae labiales inferiores
				●	Branchiomotor innervation: to the one m. derived from the 3rd arcus pharyngeus (musculus stylopharyngeus)
CN X: Nervus vagus (pp. 138–139)		Foramen jugulare	●		General somatic sensation: from ear and internal skull
			●		Taste: special visceral sensation from epiglottis and radix linguae
			●		General visceral sensation: from aortic body, pars laryngeus pharyngis and larynx, respiratory tract, and thoracoabdominal viscera
				●	Parasympathetic innervation: preganglionic fibers to small, unnamed ganglia near target organs or embedded in smooth muscle walls; postganglionic fibers to glandulae, mucosa, and smooth muscle of pharynx, larynx, and thoracic and abdominal viscera
				●	Branchiomotor innervation: to musculi pharyngis and laryngis derived from the 4th and 6th arcus pharyngei; also distributes branchiomotor fibers from CN XI
CN XI: Nervus accessorius (p. 140)		Foramen jugulare		●	Somatomotor innervation: to musculi trapezius and sternocleidomastoideus
				●	Branchiomotor innervation: to musculi laryngis (except musculus cricothyroideus) via plexus pharyngeus and CN X (*Note:* The branchiomotor fibers from the cranial root of CN XI are distributed by CN X [nervus vagus].)
CN XII: Nervus hypoglossus (p. 141)		Canalis hypoglossus		●	Somatomotor innervation: to all intrinsic and extrinsic lingual musculi (except musculus palatoglossus)

Nuclei Nervorum Cranialium

Fig. 4.72 **Nuclei nervorum cranialium: topographic arrangement**
Cross-section through the medulla spinalis and truncus encephali, superior view. Yellow = Somatic sensation. Green = Visceral sensation. Blue = Visceromotor function. Red = Somatomotor function.
The nuclei of the nervi spinales and craniales have a topographic arrangement based on embryonic migration of neuron populations.

A Embryonic medulla spinalis: Initially, the developing medulla spinalis demonstrates a posteroanterior arrangement in which the sensory (afferent) neurons are posterior and the motor (efferent) neurons are anterior. This pattern is continued into the adult medulla spinalis: the cell bodies of afferent neurons (generally secondary neurons) are located in the cornu posterius, and the cell bodies of efferent neurons (lower motor neurons and preganglionic autonomic neurons) are located in the cornua anterius and laterale, respectively.

B Early embryonic truncus encephali: Sensory neurons (in the lamina dorsolateralis) migrate laterally, whereas motor nuclei (in the lamina ventrolateralis) migrate medially. This produces a mediolateral arrangement of nuclear columns (functionally similar nuclei stacked longitudinally).

C Adult truncus encephali: The four longitudinal nuclear columns have a mediolateral arrangement (from medial to lateral): somatic efferent, visceral efferent, visceral afferent, and somatic afferent.

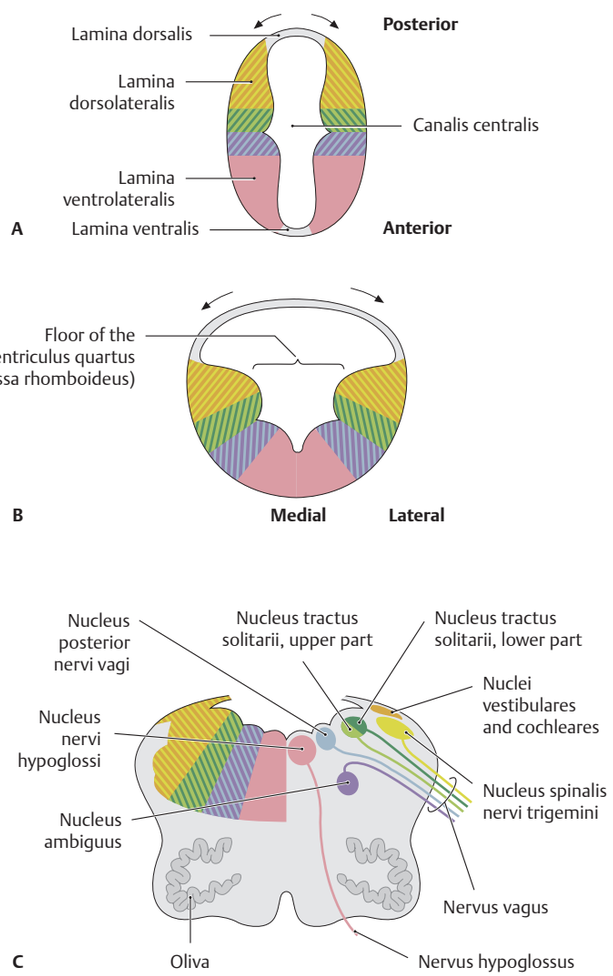


Table 4.16 **Nuclei nervorum cranialium**

There is not a 1-to-1 relationship between cranial nerve fiber types and nuclei nervorum cranialium. Some nerves derive similar fibers from multiple nuclei (e.g., CN V and CN VIII). Other nuclei are associated with multiple nerves. *Note:* The five sensory nervi craniales have eight associated sensory ganglia (cell bodies of first-order sensory neurons). The three parasympathetic nervi craniales have four associated autonomic ganglia (cell bodies of postganglionic neurons).

Nuclei	Nervus cranialis
Somatic afferent nuclear column (yellow)	
General somatosensory: Three nuclei that are primarily associated with CN V but receive fibers from other nerves.	
• Nucleus mesencephalicus nervi trigemini	CN V (via ganglion trigeminale)
• Nucleus principalis nervi trigemini	CN IX (via ganglion superius)
• Nucleus spinalis nervi trigemini	CN X (via ganglion superius)
	Possibly CN VII (via ganglion geniculi)
Special somatosensory: Six nuclei that are associated with CN VIII.* The nerve and nuclei are divided into a vestibular part (balance) and a cochlear part (hearing).	
• Nuclei vestibulares medialis, lateralis, superior, and inferior	CN VIII, vestibular root (via ganglion vestibulare)
• Nuclei cochleares anterior and posterior	CN VIII, cochlear root (via ganglia spiralia)
Visceral afferent nuclear column (green)	
General and special viscerosensory: One nuclear complex in the brainstem that consists of a superior (taste) and inferior (general visceral sensation) part and is associated with three nervi craniales.**	
• Nucleus tractus solitarii, inferior part	CN IX (via ganglion inferius)
	CN X (via ganglion inferius)
• Nucleus tractus solitarii, superior part	CN VII (via ganglion geniculi)
	CN IX (via ganglion inferius)
	CN X (via ganglion inferius)
Visceral motor nuclear column (blue)	
Parasympathetic (general visceromotor)**:** Four nuclei that each have an associated nervus cranialis and one or more ganglia.	
• Nucleus visceralis nervi oculomotorii	CN III (via ganglion ciliare)
• Nucleus salivatorius superior	CN VII (via ganglia submandibulare and pterygopalatinum)
• Nucleus salivatorius inferior	CN IX (via ganglion oticum)
• Nucleus posterior nervi vagi	CN X (via myriad unnamed ganglia near target organs)
Branchiomotor (special visceromotor)**:** Three nuclei that innervate the muscles of the arcus pharyngei via four nervi craniales.	
• Nucleus motorius nervi trigemini	CN V
• Nucleus nervi facialis	CN VII
• Nucleus ambiguus	CN IX
	CN X (with fibers from CN XI)
Somatomotor nuclear column (red)	
Five nuclei, each associated with a separate nerve.	
• Nucleus nervi oculomotorii	CN III
• Nucleus nervi trochlearis	CN IV
• Nucleus nervi abducentis	CN VI
• Nucleus nervi accessorii	CN XI
• Nucleus nervi hypoglossi	CN XII

*There are no brainstem nuclei associated with CN II because it emerges from the diencephalon.

**The special visceral afferent fibers in the nervus olfactorius (CN I) project to the telencephalon.

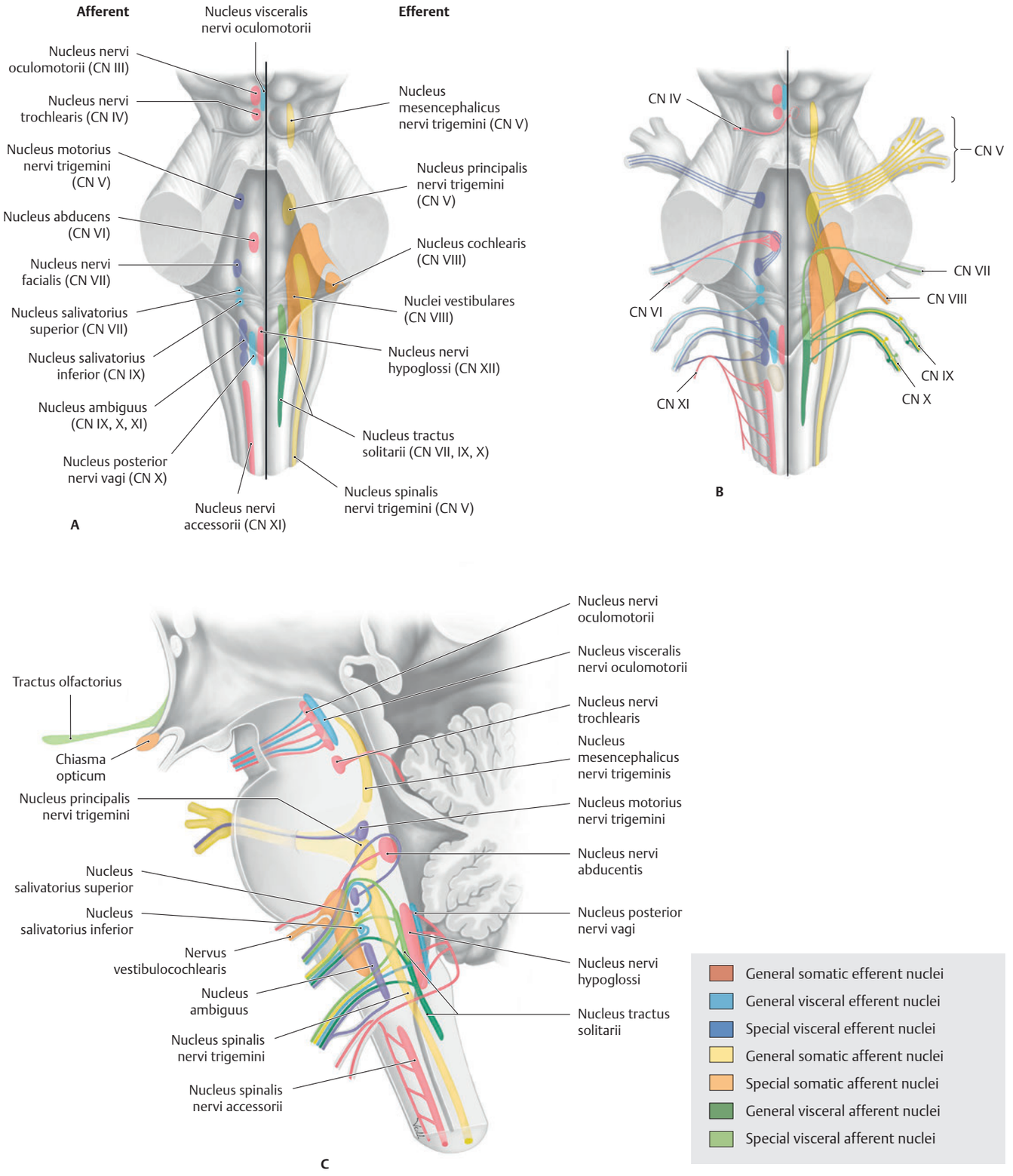


Fig. 4.73 **Nuclei nervorum cranialium: location**
A, B Posterior view of truncus encephali (cerebellum removed). **C** Left lateral view of midsagittal section. *Note:* The nervi craniales are numbered and described according to the level of their *emergence* from the truncus encephali. This does not necessarily correspond to the level of the nuclei nervi cranialis associated with the nerve.

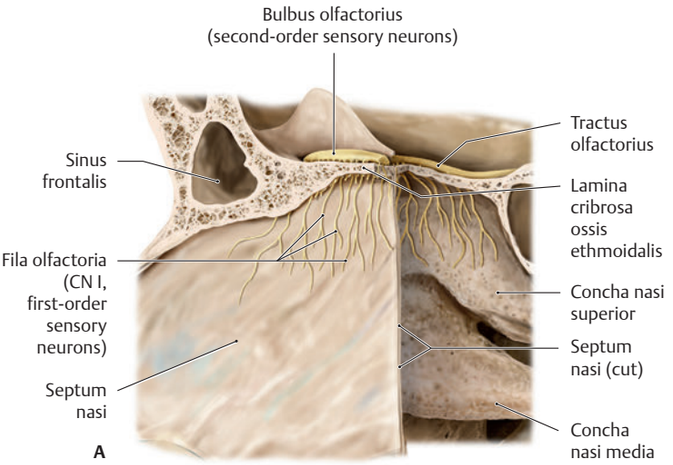
CN I & II: Nervi Olfactorius & Opticus

Neither the nervus olfactorius nor the nervus opticus is a true peripheral nerve. They are extensions of the encephalon (telencephalon and diencephalon, respectively). They are therefore both sheathed in meninges (removed here) and contain CNS-specific cells (oligodendrocytes and microglia).

Fig. 4.74 **Nervus olfactorius (CN I)**
A Left lateral view of left septum nasi and right lateral nasal wall (the posterior part of the septum nasi is cut). **B** Inferior view of encephalon. (*Shaded structures are deep to the basal surface.)
The nervus olfactorius relays smell information (special visceral afferent) to the cortex via a classical three-neuron pathway.

1. First-order sensory neurons are located in the mucosa of the upper septum nasi and concha nasi superior (**A**). These bipolar neurons form 20 or so fiber bundles collectively called the fila olfactoria (CN I). As the "olfactory region" is limited by the extent of these fibers (2–4 cm^2), the conchae nasi create turbulence, which ensures that air (and olfactory stimuli) passes over this area. The thin, unmyelinated fila olfactoria enter the fossa cranii anterior via the lamina cribrosa ossis ethmoidalis.
2. Second-order sensory neurons are located in the bulbus olfactorius (**B**). Their axons course in the tractus olfactorius to the stria olfactoria medialis or lateralis. These axons synapse in the corpus amygdaloideum, the prepiriform area, or neighboring areas.
3. Third-order neurons relay the information to the cortex cerebri.

The first-order neurons have a limited lifespan (several months) and are continuously replenished from a pool of precursor cells in the olfactory mucosa. The regenerative capacity of the olfactory mucosa diminishes with age. Injuries to the lamina cribrosa may damage the meningeal covering of the fila olfactoria, causing olfactory disturbances and liquor cerebrospinalis leakage ("runny nose" after head trauma). See p. 156 for the mechanisms of smell.



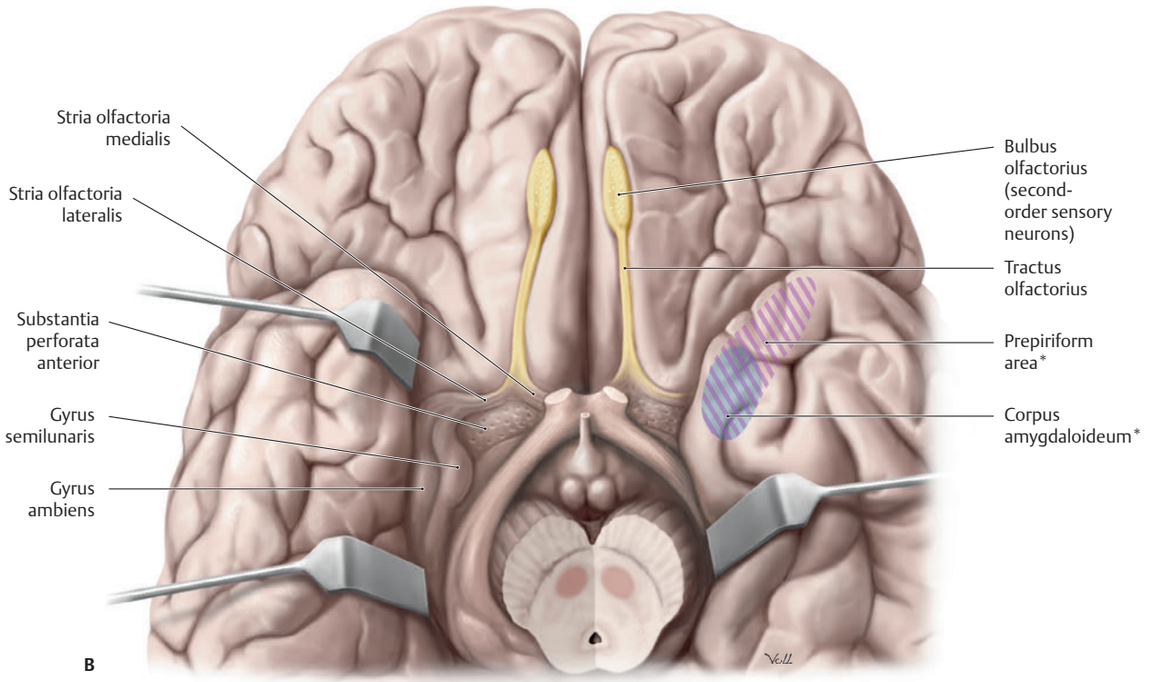
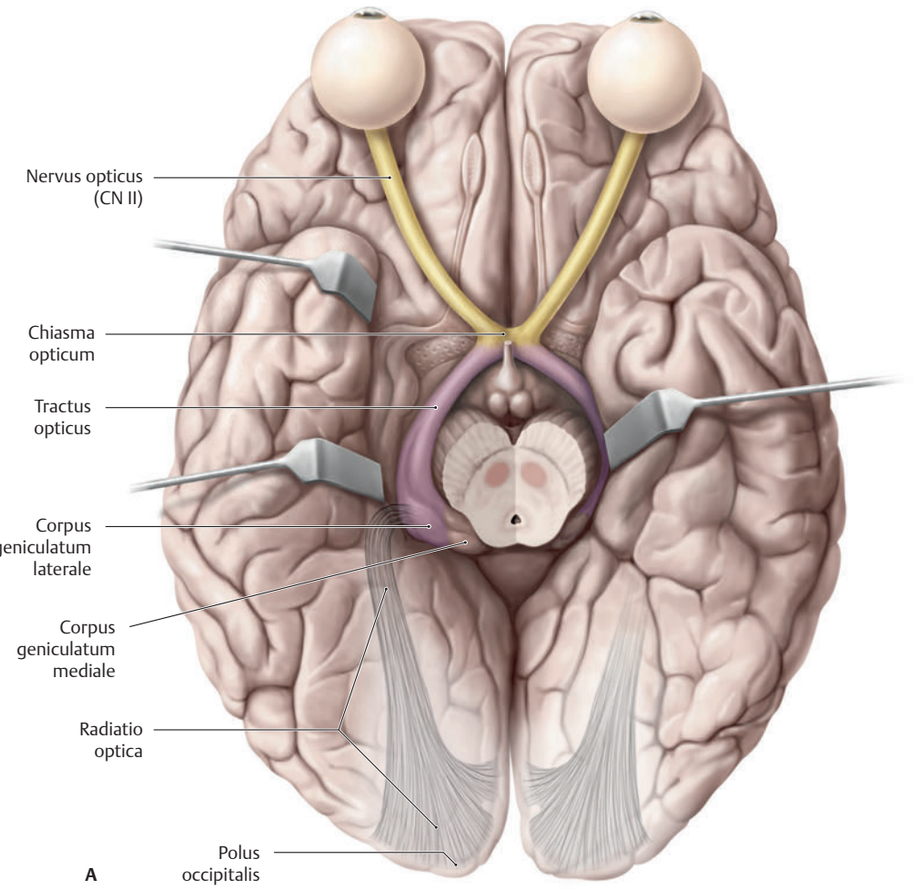
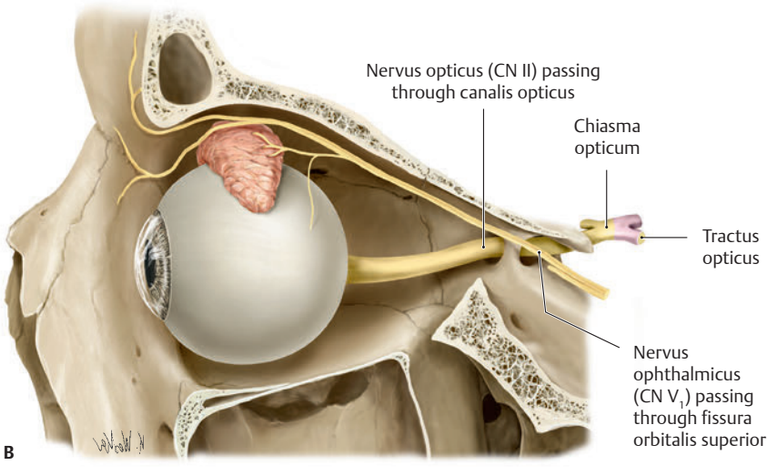
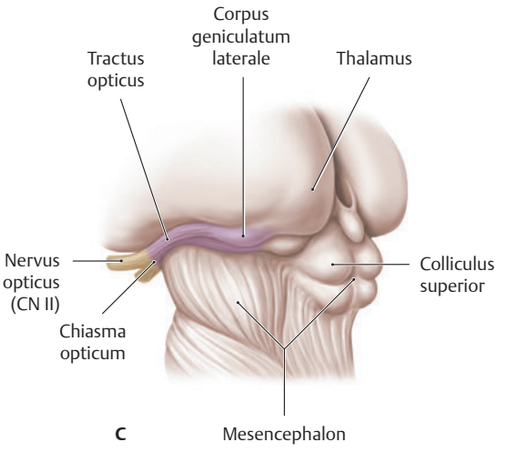


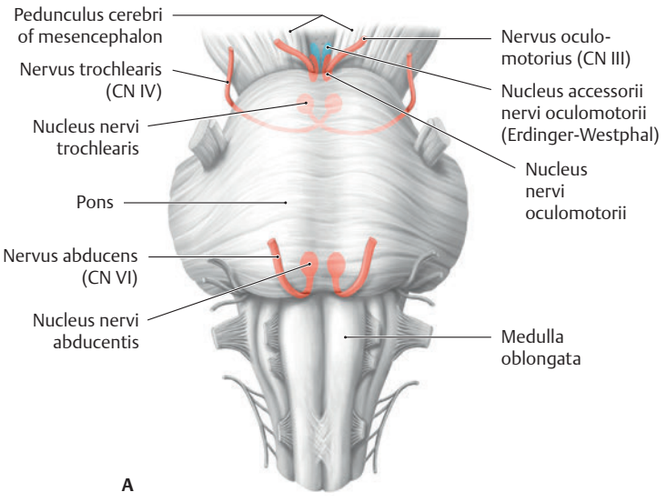
Fig. 4.75 **Nervus opticus (CN II)**
A Inferior view of encephalon. **B** Left lateral view of opened orbita. **C** Left posterolateral view of truncus encephali. The nervus opticus (special somatic afferent) relays sight information from the retina to the visual cortex (striate area) via a four-neuron pathway (see p. 254). First-order neurons (rods and cones) in the retina translate incoming photons into impulses, which are relayed to second-order bipolar neurons and third-order ganglion cells. These retinal ganglion cells combine to form the nervus opticus (CN II). The nervus opticuspasses from the orbita into the fossa cranii media via the canalis opticus (the canalis opticus is medial to the fissura orbitalis superior by which the other nervi cranii enter the orbita, **B**). Ninety percent of the third-order neurons in the nervus opticus synapse in the corpus geniculatum laterale (**C**), which then projects to the striate area. Ten percent of the third-order neurons synapse in the mesencephalon. This nongeniculate part of the visual pathway functions in unconscious and reflex action. See p. 254 for the mechanisms of sight. Lesion of the nervus opticus may cause partial or complete loss of vision, depending on the point at which the nerve is disrupted (see p. 256).







CN III, IV & VI: Nervi Oculomotorius, Trochlearis, & Abducens



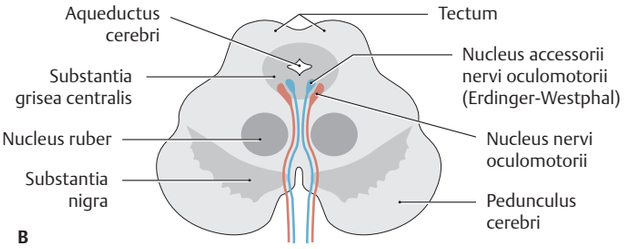


Fig. 4.76 **Nervi craniales of the extraocular muscles**
A Anterior view of truncus encephali. **B** Superior view of cross-section through the mesencephalon.
CN III, IV, and VI are the three nervi craniales that collectively innervate the six extraocular muscles. (*Note:* CN III is also involved with the parasympathetic supply to the intraocular muscles.) CN III and IV arise from nuclei in the mesencephalon (midbrain, the highest level of the truncus encephali) and emerge at roughly the same level. CN VI arises from nuclei in the pons and emerges from the truncus encephali at the pontomedullary junction.

Table 4.17 **Nervus oculomotorius (CN III)**	
Nuclei, ganglion, and fiber distribution	
Somatomotor (red)	
Nucleus nervi oculomotorii (mesencephalon)	Lower motor neurons innervate: • Musculus levator palpebrae superioris • Musculi recti superior, medialis, and inferior • Musculus obliquus inferior
Parasympathetic (blue)	
Nucleus visceralis nervi oculomotorii (mesencephalon)	Preganglionic neurons travel in the inferior division of CN III
	Postganglionic neurons in the **ganglion ciliare** innervate: Intraocular muscles (musculus sphincter pupillae and musculus ciliaris)
Course	
CN III emerges from the mesencephalon, the highest level of the truncus encephali. It runs anteriorly through the lateral wall of the sinus cavernosus to enter the orbit through the **fissura orbitalis superior**. After passing *through* the anulus tendineus communis, CN III divides into a superior and an inferior division.	
Lesions	
Lesions cause oculomotor palsy of various extents. Complete oculomotor palsy is marked by paralysis of all the innervated muscles, causing: • Ptosis (drooping of eyelid) = disabled musculus levator palpebrae superioris • Inferolateral deviation of affected eye, causing diplopia (double vision) = disabled extraocular muscles • Mydriasis (pupil dilation) = disabled musculus sphincter pupillae • Accommodation difficulties (difficulty focusing) = disabled musculus ciliaris	

Table 4.18 **Nervus trochlearis (CN IV)**	
Nucleus and fiber distribution	
Somatomotor (red)	
Nucleus nervi trochlearis (mesencephalon)	Lower motor neurons innervate: • Musculus obliquus superior
Course	
CN IV is the only nervus cranialis to emerge from the posterior surface of the truncus encephali. After emerging from the mesencephalon, it courses anteriorly around the pedunculus cerebri. CN IV then enters the orbit through the **fissura orbitalis superior**, passing *lateral* to the anulus tendineus communis. It has the longest *intra*dural course of the three extraocular motor nerves.	
Lesions	
Lesions cause nervus trochlearis palsy: • Superomedial deviation of the affected eye, causing diplopia (double vision) = disabled musculus obliquus superior *Note:* Because CN IV crosses to the opposite side, lesions close to the nucleus result in nervus trochlearis palsy on the opposite side (contralateral palsy). Lesions past the site where the nerve crosses the midline cause palsy on the same side (ipsilateral palsy).	

Table 4.19 **Nervus abducens (CN VI)**	
Nucleus and fiber distribution	
Somatomotor (red)	
Nucleus nervi abducentis (pons)	Lower motor neurons innervate: • Musculus rectus lateralis
Course	
CN VI follows a long *extra*dural path. It emerges from the pontomedullary junction (inferior border of pons) and runs through the sinus cavernosus in close proximity to the arteria carotis interna. CN VI enters the orbit through the **fissura orbitalis superior** and courses *through* the anulus tendineus communis.	
Lesions	
Lesions cause nervus abducens palsy: • Medial deviation of the affected eye, causing diplopia = disabled musculus rectus lateralis *Note:* The path of CN VI through the sinus cavernosus exposes it to injury. Sinus cavernosus thrombosis, aneurysms of the arteria carotis interna, meningitis, and subdural hemorrhage may all compress the nerve, resulting in nerve palsy. Excessive fall in CSF pressure (e.g., due to lumbar puncture) may cause the truncus encephali to descend, exerting traction on the nerve.	

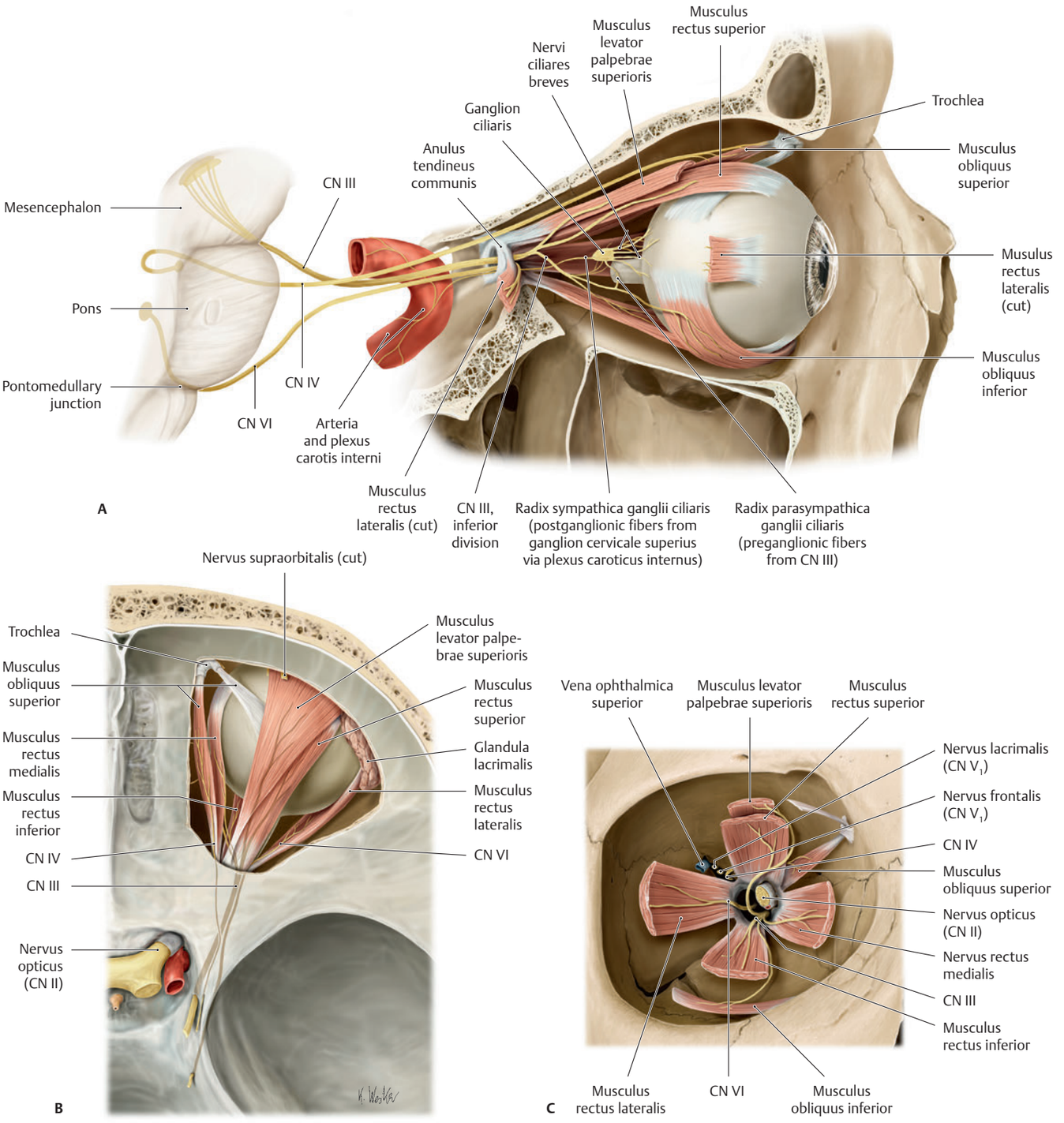


Fig. 4.77 **Nerves supplying the ocular muscles**
Right orbita. **A** Lateral view with temporal wall removed. **B** Superior view of opened orbita. **C** Anterior view. Nervi craniales III, IV, and VI enter the orbita through the fissura orbitalis superior, lateral to the canalis opticus (CN IV then passes lateral to the anulus tendineus communis, and CN III and VI pass through it). All three nerves supply somatomotor innervation to the extraocular muscles. The ganglion ciliare communicates three types of fibers (parasympathetic, sympathetic, and sensory) to and from the intraocular muscles via the nervi ciliares breves. (Only parasympathetics synapse in the ganglion ciliare. All other fibers pass through without synapsing.) The ganglion ciliare therefore has three roots:

- Parasympathetic (motor) root: Preganglionic parasympathetic fibers travel with the inferior division of CN III to the ganglion ciliare. Only the parasympathetic fibers synapse in the ganglion ciliare (the other two fiber types pass through the ganglion without synapsing).
- Sympathetic root: Postganglionic sympathetic fibers from the ganglion cervicale superius travel on the arteria carotis interna to enter the fissura orbitalis superior, where they may course along the arteria ophthalmica to enter the nervi ciliares breves via the ganglion ciliare.
- Sensory root: Sensory fibers (from the eyeball) travel to the nervus nasociliaris (CN V_1) via the ganglion ciliare.

The nervi ciliares breves therefore contain sensory fibers from the bulbus oculi and postganglionic sympathetic and parasympathetic fibers from the ganglia cervicale superius and ganglion ciliare, respectively. *Note:* Sympathetic fibers from the ganglion cervicale superius may also travel with the nervus nasociliaris (CN V_1) and reach the intraocular muscles via the nervi ciliares longi.

CN V: Nervus Trigeminus, Nuclei, & Divisions

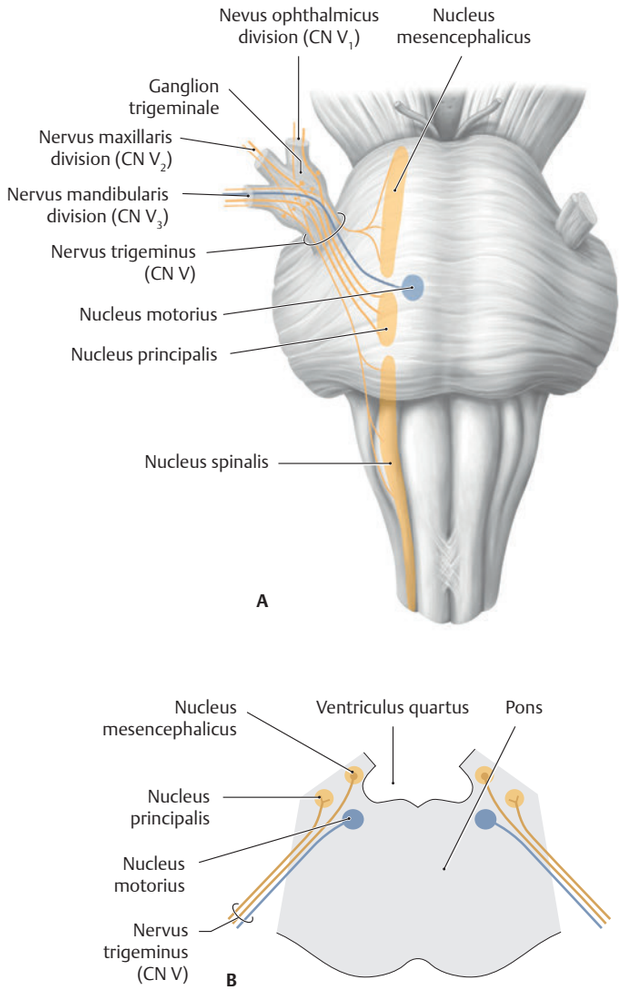


Fig. 4.78 **Nuclei nervi trigemini**
A Anterior view of truncus encephali. **B** Superior view of cross-section through the pons.
Afferent neurons in the divisions of the nervus trigeminus convey general somatic sensation (touch, pain, and temperature) to the CNS. The neurons from all three divisions synapse in three brainstem nuclei named for their locations (see **Table 4.20**):

- **Nucleus mesencephalicus nervi trigemini**
- **Nucleus principalis nervi trigemini**
- **Nucleus spinalis nervi trigemini**

Efferent fibers arise from lower motor neurons in the **nucleus motorius nervi trigemini**. These fibers exit at the radix motoria of the nervus trigeminus and unite with the nervus mandibularis division (CN V_3) in the foramen ovale. The branchiomotor fibers innervate the muscles of the first arcus pharyngeus.

Fig. 4.79 **Nervus trigeminus lesions**
Lesions of the divisions of the nervus trigeminus (peripheral nerves) will produce sensory loss following the pattern in **Fig. 4.80B** and potentially motor paralysis. Lesions of the nucleus spinalis nervi trigemini will produce sensory loss (pain and temperature) in the pattern shown here (Sölder lines). These concentric circles correspond to the somatotopic organization of the nucleus spinalis: more cranial portions receive axons from the center of the face, and more caudal portions receive axons from the periphery.

Table 4.20 **Nervus trigeminus nuclei and lesions**

Nuclei

Somatosensory (yellow)

Afferent neurons from the sensory territories of all three trigeminal divisions synapse in three brainstem nuclei named for their location.

Nucleus	Location	Sensation
Nucleus mesencephalicus	Mesencephalon	Proprioception (*Note:* The first-order sensory cell bodies of proprioceptive fibers associated with CN V have their cell bodies located in the nucleus mesencephalicus.)
Nucleus principalis	Pons	Touch
Nucleus spinalis	Medulla oblongata	Pain and temperature

Note: These sensory nuclei contain the cell bodies of second-order neurons. The nucleus mesencephalicus is an exception — it contains the cell bodies of first-order pseudounipolar neurons that have migrated into the brain.

Branchiomotor (purple)

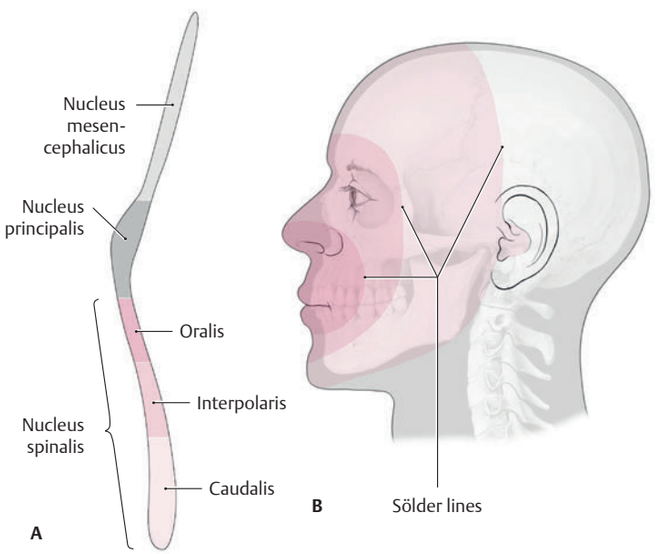
Lower motor neurons are located in the nucleus motorius nervi trigemini. They innervate the eight muscles derived from the 1st arcus pharyngeus:

- Musculus masseter
- Musculus temporalis
- Musculus pterygoideus lateralis
- Nucleus pterygoideus medialis
- Musculus tensor veli palatini
- Musculus tensor tympani
- Musculus mylohyoid
- Venter anterior musculi digastrici

Lesions

Traumatic lesions of the nervus trigeminus may cause sensory loss in corresponding territories or paralysis to the target muscles. *Note:* The afferent fibers of the nervus trigeminus compose the afferent limb of the corneal reflex (reflex eyelid closure).

- Trigeminal neuralgia is a disorder of CN V causing intense, crippling pain in the sensory territories.



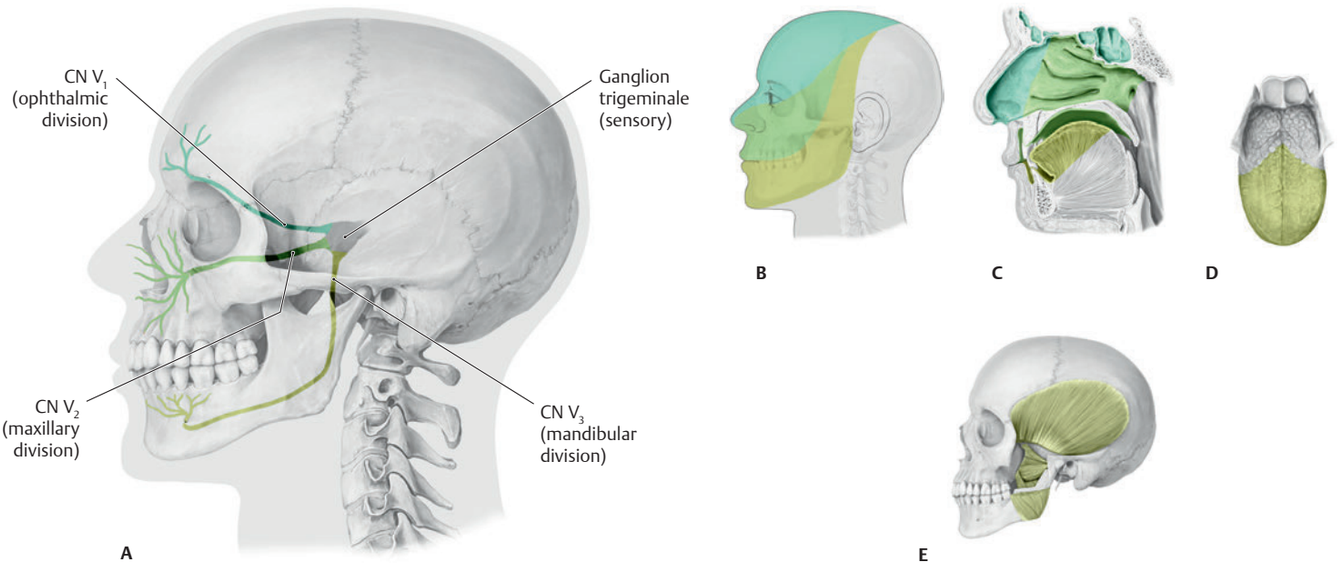


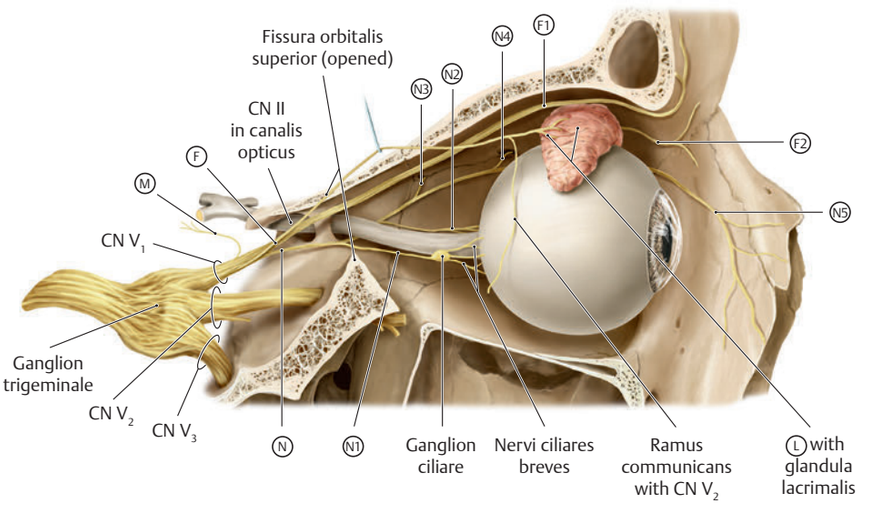
Fig. 4.80 **Nervus trigeminus divisions and distribution**
A Left lateral view of trigeminal divisions. **B–D** Somatosensory nerve territories. **E** Branchiomotor nerve territories.
The nervus trigeminus is the major sensory nerve of the face. It has three major divisions (**A**) that convey general somatic sensation (touch, pain, and proprioception) from the face (**B**) and select mucosa (**C** and **D**). The nervus trigeminus also contains branchiomotor fibers that innervate the eight muscles derived from the first arcus pharyngeus (**E**).

Table 4.21 **Nervus trigeminus (CN V) divisions and distribution**

CN V consists of a large radix sensoria and a small radix motoria, which emerge from the truncus encephali separately in the fossa cranii media at the level of the pons.			
Radix sensoria			
Fibers	**General somatosensory** (yellow): Convey general sensation (touch, pain, and temperature) from the sensory territories of CN V (see **Fig. 4.80**). The cell bodies of these first-order pseudounipolar neurons are primarily located in the ganglion trigeminale.		
Course	The sensory root is formed by three divisions that unite as the **ganglion trigeminale** in the middle fossa cranii media.	**Division**	**Distribution**
		CN V_1 (nervus ophthalmicus division)	From orbita via fissura orbitalis superior (see p. 124)
		CN V_2 (nervus maxillaris division)	From fossa pterygopalatina via foramen rotundum (see pp. 126, 144)
		CN V_3 (nervus mandibularis division)	From inferior skull base via foramen ovale (see pp. 144, 128)
Nuclei	Afferent axons from all three divisions synapse on three brainstem nuclei located in the mesencephalon, pons, and medulla oblongata.	**Nuclei**	**Sensation**
		Nucleus mesencephalicus	Proprioception (see **Table 4.20**)
		Nucleus principalis	Touch
		Nucleus spinalis	Pain and temperature
Radix motorius			
Fibers	**Branchiomotor** (purple): Conveys motor fibers to the eight muscles derived from the 1st arcus pharyngeus:	• Musculus masseter • Musculus temporalis • Musculus pterygoideus lateralis • Musculus pterygoideus medialis	• Musculus tensor veli palatini • Musculus tensor tympani • Musculus mylohyoideus • Venter anterior musculi digastrici
Course	The motor root emerges separately from the pons and unites with CN V_3 in the foramen ovale.		
Nucleus	Nucleus motorius (located in pons)		
"Scaffolding": CN V is used as scaffolding for the distribution of autonomic (sympathetic and parasympathetic) and taste fibers from other nervi craniales.			
Parasympathetic	All three branches of CN V are used to convey postganglionic parasympathetic fibers from parasympathetic ganglia. • CN VII: Preganglionic fibers from CN VII synapse in the ganglion pterygopalatinum or submandibulare, associated with CN V_2 and CN V_3, respectively. Postganglionic parasympathetic fibers then travel with the sensory branches of CN V to reach their targets. • CN IX: Preganglionic fibers synapse in the ganglion oticum; postganglionic fibers are distributed along branches of CN V_3.		
Sympathetic	Postganglionic sympathetic fibers from the ganglion cervicale superius may also be distributed by the sensory branches of CN V.		
Taste	Taste fibers from the presulcal tongue (anterior two thirds) travel via the nervus lingualis (CN V_3) to the chorda tympani (CN VII) and nuclei of CN VII.		

CN V_1: Nervus Trigeminus, Nervus Ophthalmicus Division

Fig. 4.81 **Nervus ophthalmicus division (CN V_1) of the nerus trigeminus**
Lateral view of the partially opened right orbita. The nervus ophthalmicus divides into three major branches *before* reaching the fissura orbitalis superior: the nervi lacrimalis (L), frontalis (F), and nasociliaris (N). These nerves run roughly in the lateral, middle, and medial portions of the upper orbita, respectively. The nervi lacrimalis and frontalis enter the orbita superior to the anulus tendineus communis, and the nervus nasociliaris enters through it. See **Table 4.22** for labels.



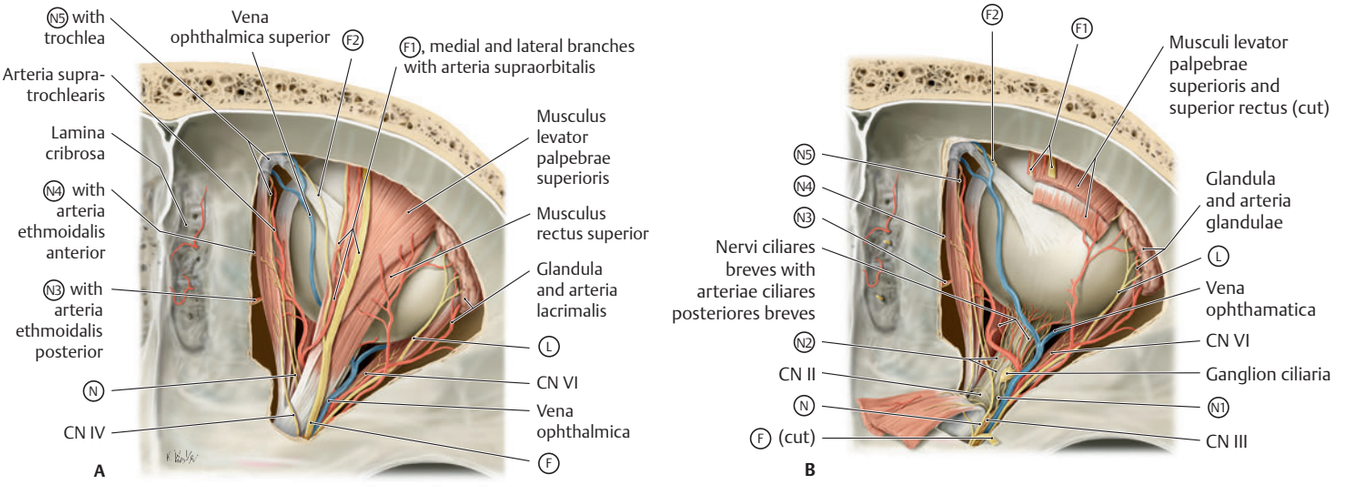


Fig. 4.82 **Nervus ophthalmicus divisions in the orbit**
Superior view of orbita. (*Removed:* Bony roof, periorbita, and periorbital fat.) See **Table 4.22** for labels. **A** Nervi lacrimalis, frontalis, and nasociliaris. **B** Nervus nasociliaris and ganglion ciliare. (*Cut:* Musculus rectus superior and musculus levator palpebrae superioris.)
The *extra*ocular muscles receive somatomotor innervation from the nervi oculomotorius (CN III), trochlearis (CN IV), and abducens (CN VI). The *intra*ocular muscles receive autonomic (sympathetic and parasympathetic) innervation via the nervi ciliares breves and longi. Sympathetic fibers from the ganglion cervicale superius ascend on the arteria carotis interna and travel in two manners: they may join the nervus nasociliaris (CN V_1), which distributes them as the nervi ciliares longi, or they may course along the arteria ophthalmica to enter the ganglion ciliare as the *radix sympathica*. The ganglion ciliare also receives parasympathetic fibers from CN III (via the *radix parasympathica*). The ganglion distributes these sympathetic and parasympathetic fibers via the nervi ciliares breves. The nervi ciliares breves contain sensory fibers, which enter the nervus nasociliaris via the *radix sensoria* of the ganglion ciliare.

Table 4.22 Nervus ophthalmicus (CN V_1)

The nervus ophthalmicus (CN V_1) is a sensory nerve* that conveys fibers from structures of the superior facial skeleton to the ganglion trigeminale. CN V_1 gives off one branch in the fossa cranii media before dividing into three major branches, which pass through the fissura orbitalis superior into the orbita. The nervi lacrimalis, frontalis, and nasociliaris travel in the lateral, middle, and medial portions of the upper orbit, respectively.

Ⓜ **Ramus meningeus recurrens**	Sensory: Dura mater of the fossa cranii media.	
Ⓛ **Nervus lacrimalis**	The smallest of the three major branches, the nervus lacrimalis runs in the superolateral orbita.	
Opening	Fissura orbitalis superior (above the anulus tendineus communis).	
Course	Runs (with the arteria lacrimalis) along the superior surface of the musculus rectus lateralis, through the glandula lacrimalis and septum orbitale to the skin of the upper eyelid.	
Innervation	Sensory: Upper eyelid (skin and conjunctiva) and glandula lacrimalis.	
	Sensory and parasympathetic: Glandula lacrimalis. Postganglionic parasympathetic secretomotor fibers from the ganglion pterygopalatinum of the nervus facialis (CN VII) travel with the nervus zygomaticus and ramus zygomaticotemporalis (CN V_2). They enter the sensory nervus lacrimalis (CN V_1) via a ramus communicans and are distributed to the gland. Postganglionic sympathetic fibers follow a similar path.	
Ⓕ **Nervus frontalis**	The largest of the three major branches, the nervus frontalis runs in the middle of the upper orbita.	
Opening	Fissura orbitalis superior (above the anulus tendineus communis).	
Course and branches	Runs along the superior surface of the musculus levator palpebrae superioris, below the periosteum. At roughly the level of the posterior bulbus oculi, the nervus frontalis divides into two terminal branches:	
	Ⓕ1 **Nervus supraorbitalis**	Continues on the superior surface of the musculus levator palpebrae superioris and passes through the foramen supraorbitale (incisura supraorbitalis).
	Ⓕ2 **Nervus supratrochlearis**	Courses anteromedially with the arteria supratrochlearis toward the trochlea (tendo of musculus obliquus superior) and passes through the incisura frontalis.
Innervation	Sensory: Upper eyelid (skin and conjunctiva) and the skin of the forehead (both branches). The nervus supraorbitalis also receives fibers from mucosa of sinus frontalis; the nervus supratrochlearis communicates with the nervus infratrochlearis.	
Ⓝ **Nervus nasociliaris**	The nervus nasociliaris runs in the middle and medial parts of the upper orbita.	
Opening	Fissura orbitalis superior (via the anulus tendineus communis).	
Course and branches	Runs medially (across the nervus opticus [CN II]) and then anteriorly between the musculi obliquus superior and rectus medialis. Gives off three branches (two sensory and one sympathetic) before dividing into two terminal branches (nervi ethmoidalis anterior and infratrochlearis).	
	Ⓝ1 **Radix sensoria ganglii ciliaris**	Sensory: Fibers from the **nervi ciliares breves** pass without synapsing through the ganglion ciliare and enter the nervus nasociliaris via the radix sensoria.
	Ⓝ2 **Nervi ciliares longi**	Sensory: Eye (e.g., cornea and sclera).
	Ⓝ3 **Nervus ethmoidalis posterior**	Sensory: Cellulae ethmoidales and sinus sphenoidalis. Fibers run in the os ethmoidale (posterior ethmoid canal) to the nervus nasociliaris.
	Ⓝ4 **Nervus ethmoidalis anterior**	Sensory: Superficial nose and anterior cavitas nasi. • **Rami nasalis interni:** Mucosa of the anterior portions of the septum nasi (rami nasales mediales) and lateral nasal wall (rami nasales laterales). • **Ramus nasalis externus:** Skin of the nose (courses under the musculus nasalis). Fibers from these two terminal branches ascend via the os nasale, course posteriorly in the cavitas cranii over the lamina cribrosa, and enter the orbita via the anterior ethmoid canal.
	Ⓝ5 **Nervus infratrochlearis**	Sensory: Medial aspect of the upper eyelid (skin and conjunctiva) and the saccus lacrimalis. Fibers enter the orbita near the trochlea (tendo of musculus obliquus superior) and course posteriorly to the nervus nasociliaris.
Innervation	Sensory: Cellulae ethmoidales, sinus sphenoidalis, anterior cavitas nasi, superficial nose, upper eyelid, saccus lacrimalis, and eye.	

**Note:* Nerve courses are traditionally described proximal to distal (CNS to periphery). However, for sensory nerves, the sensory relay is in the opposite direction. It is more appropriate to talk of sensory nerves collecting fibers than to talk of them branching to supply a region.

CN V_2: Nervus Trigeminus, Nervus Maxillaris Division

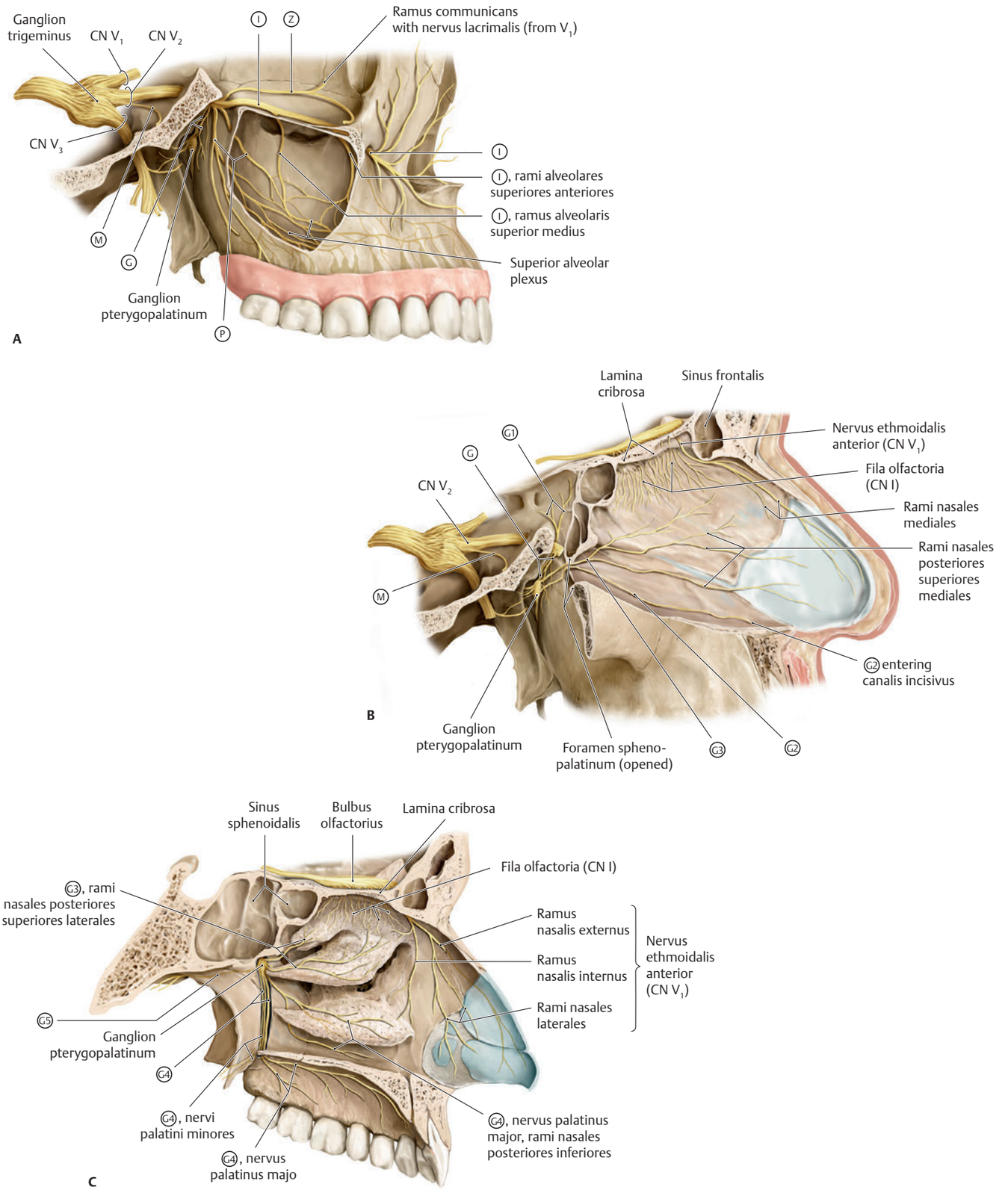


Fig. 4.83 **Nervus maxillaris (CN V_2) of the nervus trigeminus**
Right lateral view. See **Table 4.23** for labels. **A** Opened right sinus maxillaris. **B** Septum nasi in right cavitas nasi. **C** Left lateral nasal wall.

Table 4.23 Nervus maxillaris (CN V_2)

Like the nervus ophthalmicus (CN V_1), the nervus maxillaris (CN V_2) is a sensory nerve* that conveys fibers from structures of the facial skeleton to the ganglion trigeminus. CN V_2 gives off one branch in the fossa cranii media before entering the foramen rotundum to the fossa pterygopalatina. In the fossa pterygopalatina, the nervus maxillaris divides into branches (e.g., nervi zygomaticus, alveolares superiores, and infraorbitalis) and receives ganglionic branches from the ganglion pterygopalatinum. This ganglion has five major branches, which distribute CN V_2 fibers. These sensory CN V_2 fibers convey autonomic fibers from the ganglion pterygopalatinum.

Direct branches of the nervus maxillaris (CN V_2)

Ⓜ **Ramus meningeus**	Sensory: Meninges of the fossa cranii media.
Ⓖ **Rami ganglionares**	Generally, two ganglionic branches suspend (pass through) the **ganglion pterygopalatinum** from CN V_2 (see below).
Ⓩ **Nervus zygomaticus**	Sensory: Skin of the temple (**ramus zygomaticotemporalis**) and cheek (**ramus zygomaticofacialis**). Fibers enter the orbita via canals in the os zygomaticum and course in the lateral orbita wall to CN V_2 via the fissura orbitalis inferior.
Ⓟ **Rami alveolares superiores posteriores**	Sensory: Dentes molares maxillares (with associated gingivae and buccal mucosa) and sinus maxillaris. Fibers course on the infratemporal surface of the maxilla. The rami alveolares superiores posteriores contribute to the **superior alveolar plexus** (rami alveolares superiores anteriores, medius, and posteriores).
Ⓘ **Nervus infraorbitalis**	Sensory: Lower eyelid (skin and conjunctiva), sinus maxillaris, and dentes maxillares (via rami alveolares superiores anteriores and medius). • **Ramus alveolaris superior medius:** Sensory fibers from the dentes premolares maxillares (with associated gingivae, buccal mucosa, and sinus maxillaris). (The occurrence is variable). • **Rami alveolares superiores anteriores:** Sensory fibers from the dentes incisivi and canini maxillares (with associated gingivae, lingual mucosa, and maxillary sinus). Nasal branch: Sensory fibers from anterior portions of the nasal wall, floor, and septum. These fibers enter the canalis infraorbitalis and emerge from the sulcus infraorbitalis.

Branches passing through the ganglion pterygopalatinum: The ganglion pterygopalatinum is a parasympathetic ganglion of the nervus facialis (CN VII). It conveys first-order sensory fibers to CN V_2 from five major branches supplying the orbita, cavitas nasi, palata durum and molle, and pars nasalis pharyngis.

Ⓖ1 **Rami orbitales**	Sensory: Orbital periosteum (via fissura orbitalis inferior) and sinus paranasales (cellulae ethmoidales and sinus sphenoideus, via the posterior ethmoid canal).
Ⓖ2 **Nervus nasopalatinus**	Sensory: Anterior palatum durum and the inferior septum nasi. The left and right nervi nasopalatini ascend (in the anterior and posterior foramina incisiva, respectively) and converge in the fossa incisiva. They travel posterosuperiorly on the septum nasi (vomer) through the foramen sphenopalatinum.
Ⓖ3 **Rami nasales posteriores superiores**	Sensory: Posterosuperior cavitas nasi. (*Note:* The nervus ethmoidalis anterior [CN V_1] conveys fibers from the anterosuperior portion.) • **Rami nasales posteriores superiores laterales:** Posterior cellulae ethmoidales and mucosa in the posterior of the conchae nasi superior and media. • **Rami nasales posteriores superiores mediales:** Mucosa of the posterior nasal roof and septum.
Ⓖ4 **Nervi palatini**	Sensory: Palata durum and molle. • **Nervus palatinus major:** Palatum durum (gingivae, mucosa, and glands) and palatum molle via canalis palatinus major. Receives fibers from the concha nasi inferior and walls of the meatus nasi medius and inferior through the lamina perpendicularis of the os ethmoidale (rami nasales posteriores inferiores). • **Nervus palatinus minor:** Palatum molle, tonsillae palatinae, and uvula via canalis palatinus minor. The nervi palatini major and minor converge in the canalis palatinus major.
Ⓖ5 **Nervus pharygeus**	Sensory: Mucosa of the superior pars nasalis pharyngis via canalis palatovaginalis (pharyngus).

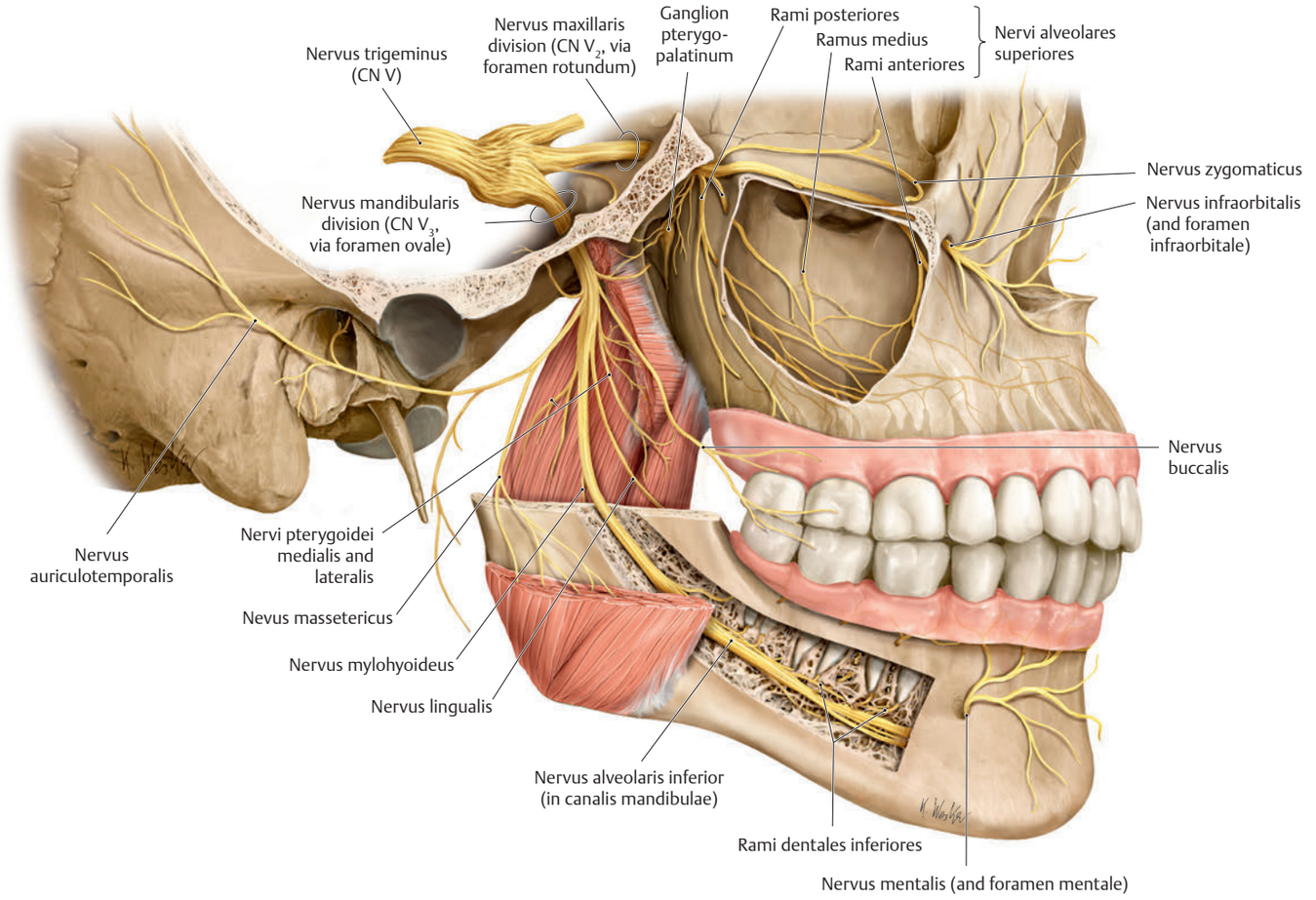
Autonomic scaffolding: The ganglion pterygopalatinum is affiliated with the sensory CN V_2. Postganglionic autonomic fibers are distributed by sensory fibers of CN V_2.

Ganglion pterygopalatinum (CN VII)	**Radix parasympathica:** Preganglionic parasympathetic fibers from the nervus facialis (CN VII) travel in the **nervus petrosus major** (joins with nervus petrosus profundus to form nervus canalis pterygoidei).
	Radix sympathica: Postganglionic sympathetic fibers from the ganglion cervicale superius ascend (via the plexus caroticus internus) and travel in the **nervus petrosus profundus** (joins with nervus petrosus major to form nervus canalis pterygoidei).
	Radix sensoria: Sensory fibers pass through the ganglion from five sensory branches (see above).

- **Glandula lacrimalis:** Postganglionic parasympathetic secretomotor fibers to the glandula lacrimalis leave the ganglion pterygopalatinum on the nervus zygomaticus (CN V_2). They travel with the amus zygomaticotemporalis to the nervus lacrimalis (CN V_1) via a ramus communicans.
- **Glandulae cavitatis oris:** Postganglionic parasympathetic fibers to the glandulae of the palatine, pharyngeal, and nasal mucosa reach their targets via corresponding sensory branches of CN V_2.
- **Blood vessels:** Postganglionic sympathetic fibers are distributed by CN V_2.
- **Taste** (CN VII)**:** Taste fibers (special visceral afferent) associated with CN VII ascend from the palatum to the nervus petrosus major and ganglion geniculi of CN VII via the nervi palatini.

**Note:* Nerve courses are traditionally described proximal to distal (CNS to periphery). However, for sensory nerves, the sensory relay is in the opposite direction. It is more appropriate to talk of sensory nerves collecting fibers than to talk of them branching to supply a region.

CN V_3: Nervus Trigeminus, Nervus Mandibularis Division



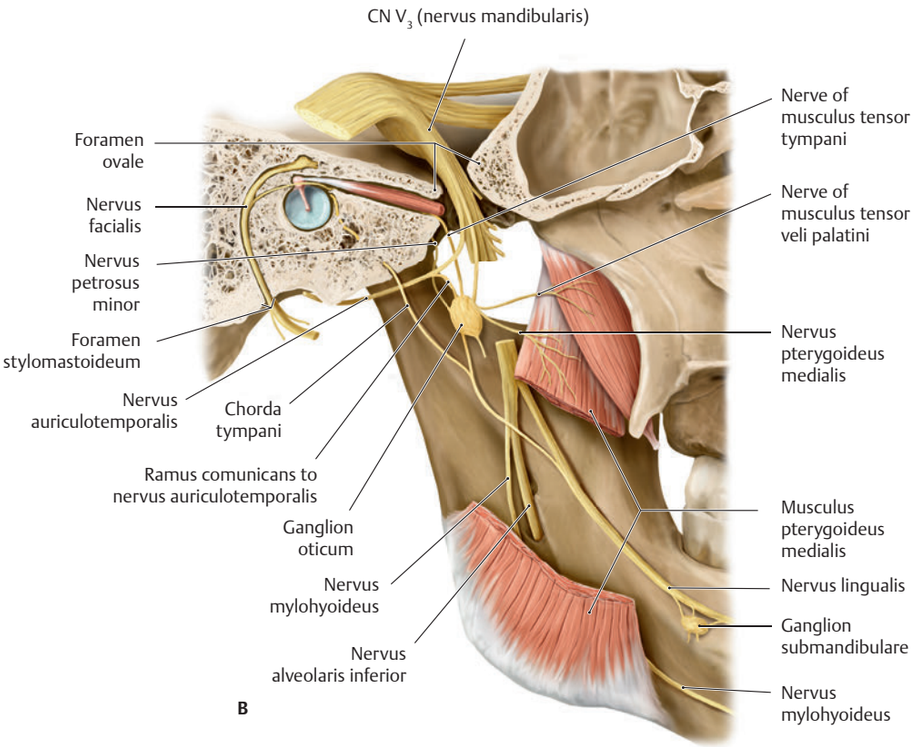


Fig. 4.84 **Nervus mandibularis division (CN V_3) of the nervus trigeminus**
Right lateral view. **A** Partially opened mandibula with fossa cranii media windowed. **B** Opened cavitas oris (right half of mandibula removed).
The trunk of CN V_3 gives off two branches (ramus meningeus and nervus pterygoideus medialis) before splitting into an anterior and a posterior division (see **Table 4.24**). The nervus pterygoideus medialis conveys branchiomotor fibers to the ganglion oticum; these fibers pass without synapsing to innervate the musculi tensores tympani and veli palatini. The ganglion oticum is the parasympathetic ganglion of the nervus glossopharyngeus (CN IX). Preganglionic fibers enter via the nervus petrosus minor (reconstituted from the plexus tympanicus; see p. 137). Postganglionic fibers leave with the nervus auriculotemporalis (CN V_3) to innervate the glandulae buccales. Taste fibers of CN VII travel in the nervus lingualis (CN V_3) to the chorda tympani (which they enter either directly or indirectly via the ganglion oticum). These fibers ascend in the chorda tympani via the cavitas tympani to the nervus facialis (CN VII; see p. 131).

Table 4.24 Nervus mandibularis (CN V_3)

The nervus mandibularis (CN V_3) is the mixed afferent-efferent branch of CN V, containing general sensory fibers and branchiomotor fibers to the eight muscles derived from the 1st arcus pharyngeus. The large sensory and small motor roots of CN V leave the fossa cranii media via the foramen ovale. In the fossa infratemporalis, they unite to form the CN V_3 trunk. The trunk gives off two branches before splitting into an anterior and a posterior division. Of the eight arcus pharyngeus primus muscles, three are supplied by the trunk, three by the anterior division, and two by the posterior division.

Trunk: The trunk of CN V_3 gives off one sensory and one motor branch. The motor branch conveys branchiomotor fibers to three of the eight muscles of the 1st arcus pharyngeus.

(R) **Ramus meningeus** (nervus spinosus)	Sensory: Dura of the fossa cranii media (also fossa cranii anterior and calvarium). The nervus spinosus arises in the fossa infratemporalis and re-enters the fossa cranii media via the foramen spinosum.
(MP) **Nervus pterygoideus medialis**	Branchiomotor: Directly to the **musculus pterygoideus medialis**. Certain fibers enter the ganglion oticum via the motor root and pass without synapsing to: • Nervus musculi tensoris veli palatini: **Musculus tensor veli palatini**. • Nervus musculus tensoris tympani: **Musculus tensor tympani**.

Anterior division: The anterior division of CN V_3 contains predominantly efferent fibers (with one sensory branch, the nervus buccalis). The branchiomotor fibers innervate three of the eight muscles of the 1st arcus pharyngeus.

(M) **Nervus massetericus**	Branchiomotor: **Musculus masseter**.
	Sensory: Articulatio temporomandibularis (articular branches).
(T) **Nervi temporales profundi**	Branchiomotor: **Musculus temporalis** via two branches: • Anterior nervus temporalis profundus • Posterior nervus temporalis profundus
(LP) **Nervus pterygoideus lateralis**	Branchiomotor: **Musculus pterygoideus lateralis**.
(B) **Nervus buccalis**	Sensory: Cheek (skin and mucosa) and buccal gingivae of the molars.

Posterior division: The larger posterior division of CN V_3 contains predominantly afferent fibers (with one motor branch, the nervus mylohyoideus). The nervus mylohyoideus arises from the nervus alveolaris inferior and supplies the remaining two muscles of the 1st arcus pharyngeus.

(A) **Nervus auriculotemporalis**	Sensory: Skin of the ear and temple. Fibers pass through the glandula parotidea, behind the articulatio temporomandibularis, and into the fossa infratemporalis. The nerve typically splits around the arteria meningea media (a branch of the arteria maxillaris) before joining the posterior division. Distributes postganglionic parasympathetic fibers from the ganglion oticum.
(L) **Nervus lingualis**	Sensory: Mucosa of the cavitas oris (presulcal tongue, oral floor, and gingival covering of facies lingualis of dentes mandibulares). In the fossa infratemporalis, the nervus lingualis combines with the chorda tympani (CN VII).
(I) **Nervus alveolaris inferior**	Sensory: Dentes mandibulares and chin: • **Incisive branch:** Dentes incisivi, canini, and premolares primi (with associated labial gingivae). • **Nervus mentalis:** Labial gingivae of the dentes incisivi and the skin of the lower lip and chin. The nervus mentalis enters the foramen mentale and combines with the incisive branch in the canalis mandibulae. The nervus alveolaris inferior exits the mandibula via the foramen mandibulae and combines to form the posterior division of CN V_3. *Note:* Dentes premolares secundi and molares mandibulares are supplied by the nervus alveolaris inferior before it splits into its terminal branches.
	Branchiomotor: Fibers branch just proximal to the foramen mandibulae: • **Nervus mylohyoideus: Musculus mylohyoideus** and venter anterior of the **musculus digastricus**.

Autonomic scaffolding: The parasympathetic ganglia of CN VII (ganglion submandibulare) and CN IX (ganglion oticum) are functionally associated with CN V_3.

Ganglion submandibulare (CN VII)	Parasympathetic root	Preganglionic parasympathetic fibers from the nervus facialis (CN VII) travel to the ganglion in the **chorda tympani**, nervus facialis, and nervus lingualis (CN V_3).
	Sympathetic root	Sympathetic fibers from the **ganglion cervicale superius** ascend (via the plexus caroticus internus) and travel in a plexus on the arteria facialis.
Ganglion oticum (CN IX)	Parasympathetic root	Preganglionic parasympathetic fibers enter from CN IX via the **nervus petrosus minor**.
	Sympathetic root	Postganglionic sympathetic fibers from the **ganglion cervicale superius** enter via a plexus on the arteria meningea media.

- **Glandula parotidea:** Postganglionic parasympathetic fibers from the ganglion oticum travel to the glandula parotidea via the nervus auriculotemporalis (CN V_3).
- **Glandulae submandibularis and sublingualis:** Postganglionic autonomic fibers to the glandulae submandibularis and sublingualis travel from the ganglion submandibulare via glandular branches.

- **Taste** (CN VII)**:** Taste fibers (special viscerosensory fibers) to CN VII may travel via the nervus lingualis (CN V_3) to the chorda tympani (CN VII).

Note: Nerve courses are traditionally described proximal to distal (CNS to periphery). However, for sensory nerves, the sensory relay is in the opposite direction. It is more appropriate to talk of sensory nerves collecting fibers than to talk of them branching to supply a region.

CN VII: Nervus Facialis, Nuclei & Internal Branches

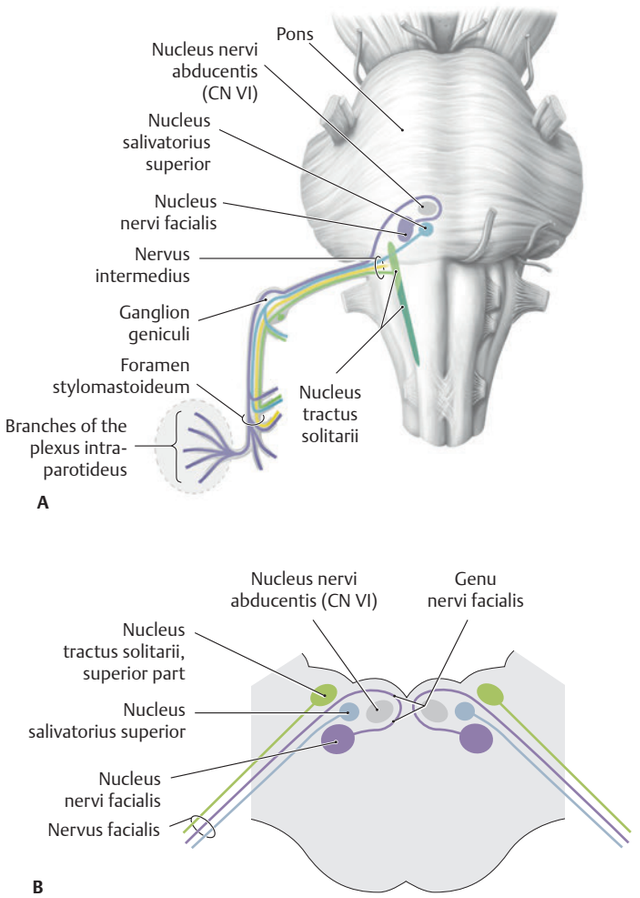


Fig. 4.85 **Nervus facialis (CN VII)**
A Anterior view of truncus encephali. **B** Superior view of cross-section through pons.
Fibers: The nervus facialis provides branchiomotor innervation to the muscles of the second arcus pharyngeus and parasympathetic motor innervation to most glandulae salivariae (via the ganglia pterygopalatinum and submandibulae). Taste fibers are conveyed via pseudounipolar sensory neurons with cell bodies in the ganglion geniculi. The nervus facialis also receives general sensation from the auris externa.
Branches: The superficial branches of CN VII are primarily branchiomotor (only the nervus auricularis posterior may contain sensory fibers as well as motor). Taste and preganglionic parasympathetic fibers travel in both the chorda tympani and nervus petrosus major. These fibers converge in the geniculum and enter the truncus encephali together as the nervus intermedius.

Table 4.25 **Nervus facialis (CN VII)**

Nuclei, ganglia, and fiber distribution	
Branchiomotor (purple)	
Nucleus nervi facialis	Lower motor neurons innervate all muscles of the 2nd arcus pharyngeus: • Musculi faciei • Musculus stylohyoideus • Venter posterior musculi digastrici • Musculus stapedius
Parasympathetic (blue)	
Nucleus salivatorius superior	Preganglionic neurons synapse in the **ganglion pterygopalatinum** or **submandibulae**.
	Postganglionic neurons innervate: • Glandula lacrimalis • Glandulae submandibularis and sublingualis • Glandulae salivariae minores of the cavitates oris and nasi
Special visceral afferent (light green)	
Nucleus tractus solitarii	First-order pseudounipolar cells in the **ganglion geniculi** relay taste sensation from the presulcal tongue (anterior two thirds) and palatum molle (via the chorda tympani and nervus petrosus major).
General somatic afferent (yellow)	
First-order pseudounipolar cells in the **ganglion geniculi** relay general sensation from the auris externa (auriculus and skin of the porus acusticus externus) and lateral membrana tympanica.	
Course	
Emergence: Axons from the nucleus salivatorius superior and the nucleus tractus solitarius form the **nervus intermedius**. These combine with the branchiomotor and somatosensory fibers to emerge from the truncus encephali as CN VII. **Internal branches:** CN VII enters the pars petrosa ossis temporalis via the meatus acusticus internus. Within the canalis nervi facialis, it gives off one branchiomotor branch (Nervus stapedius) and two nerves (nervus petrosus major and chorda tympani) containing both parasympathetic and taste fibers. **External branches:** The remaining fibers emerge via the foramen stylomastoideum. Three direct branches arise before the fibers enter the glandula parotidea (ramus digastricus, ramus stylohyoideus, and nervus auricularis posterior). In the gland, the branchiomotor fibers branch to form the plexus intraparotideus, which innervates the muscles of the 2nd arcus pharyngeus.	
Lesions	
CN VII is most easily injured in its distal portions (after emerging from the glandula parotidea). Nerve lesions of the plexus intraparotideus cause muscle paralysis. Os temporale fractures may injure the nerve within the canalis nervi facialis, causing disturbances of taste, lacrimation, salivation, etc. (see **Fig. 4.86**).	

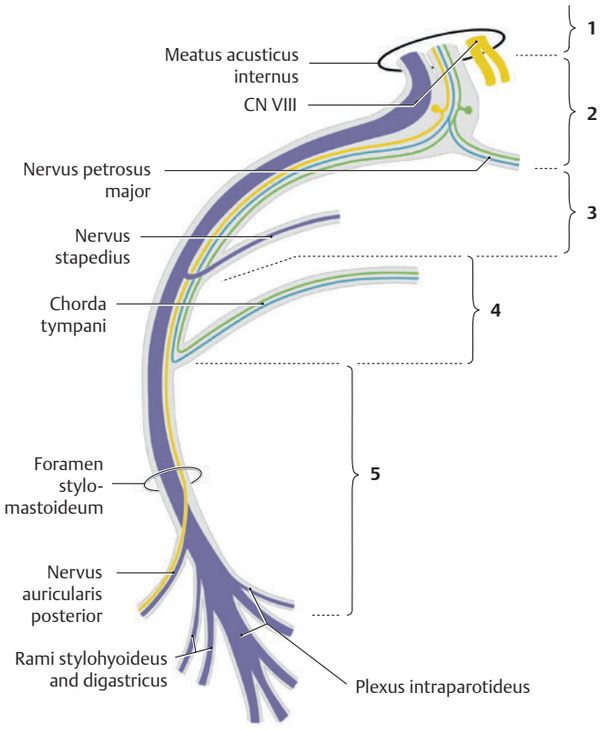
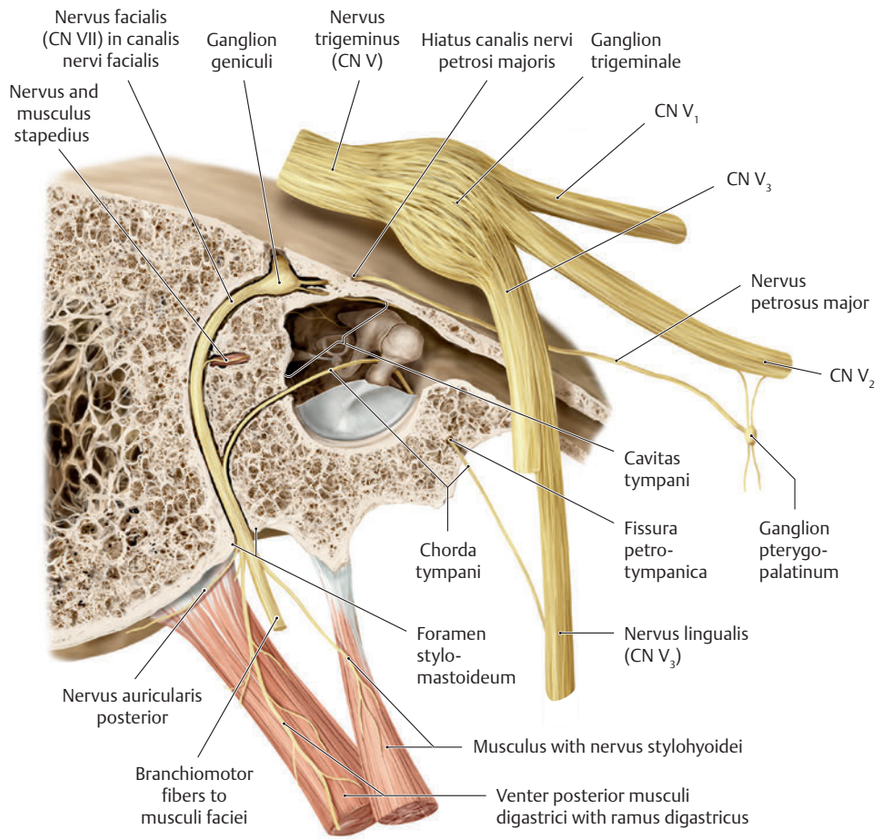


Fig. 4.86 **Branches of the nervus facialis**
The nervus facialis enters the canalis nervi facialis of the pars petrosa ossis temporalis via the meatus acusticus internus. Most branchiomotor fibers and all somatosensory fibers emerge via the foramen stylomastoideum. Within the canalis nervi facialis, CN VII gives off one branchiomotor branch and two nerves containing both parasympathetic and taste fibers (nervus petrosus major and chorda tympani). Os temporale fractures may injure the facial nerve at various levels:

1 Meatus acusticus internus: Lesions affect CN VII and the nervus vestibulocochlearis (CN VIII). Peripheral motor facial paralysis is accompanied by hearing loss and dizziness.
2 Geniculum: Peripheral motor facial paralysis is accompanied by disturbances of taste sensation, lacrimation, and salivation (nervus petrosus major).
3 Motor paralysis is accompanied by disturbances of salivation and taste (chorda tympani). Paralysis of the musculus stapedius causes hyperacusis (hypersensitivity to normal sounds).
4 Facial paralysis is accompanied by disturbances of taste and salivation (chorda tympani).
5 Facial paralysis is the only manifestation of a lesion at this level.

Fig. 4.87 **Course of the nervus facialis**
Right lateral view of right pars petrosa ossis temporalis. Both the nervus facialis and nervus vestibulocochlearis (CN VIII, not shown) pass through the meatus acusticus internus on the posterior surface of the pars petrosa. The nervus facialis courses laterally in the bone to the geniculum, which contains the **ganglion geniculi** (cell bodies of first-order pseudounipolar sensory neurons). At the geniculum (L. *genu* = knee), CN VII bends and descends in the canalis nervi facialis. It gives off three branches between the ganglion geniculi and the foramen stylomastoideum:

- **Nervus petrosus major:** Parasympathetic and taste (special visceral afferent) fibers branch from the ganglion geniculi in the greater petrosal canal. They emerge on the anterior surface of the pars petrosa and continue across the surface of the foramen lacerum. The nervus petrosus major combines with the nervus petrosus profundus in the canalis pterygoideus (nervus canalis pterygoidei, vidian nerve). The nervus petrosus major contains the fibers that form the motor root of the ganglion pterygopalatinum (the parasympathetic ganglion of CN VII). The ganglion pterygopalatinum distributes autonomic fibers via the nervus trigeminus (primarily the nervus maxillaris division, CN V_2).
- **Nervus stapedius:** Branchiomotor fibers innervate the musculus stapedius.
- **Chorda tympani:** The remaining parasympathetic and taste fibers leave the nervus facialis as the chorda tympani. This nerve runs through the cavitas tympani and fissura petrotympanica to the fossa infratemporalis, where it unites with the nervus lingualis (CN V_3).



The remaining fibers (branchiomotor with some general sensory) exit via the foramen stylomastoideum.

CN VII: Nervus Facialis, External Branches & Ganglia

Fig. 4.88 **Innervation of the arcus pharyngeus secundus muscles**

Left lateral view. The branchiomotor fibers of CN VII innervate all the muscles derived from the second arcus pharyngeus. With the exception of the nervus stapedius (to the musculus stapedius), all branchiomotor fibers in the nervus facialis emerge from the canalis nervi facialis via the foramen stylomastoideum. Three branches arise *before* the plexus intraparotideus:

- Nervus auricularis posterior (*Note:* This may also contain general somatosensory fibers.)
- Ramus digastricus
- Ramus stylohyoideus

The remaining branchiomotor fibers then enter the glandula parotidea where they divide into two trunks (temporofacial and cervicofacial) and five major branches, which innervate the musculi faciei:

- Rami temporales
- Rami zygomatici
- Rami buccales
- Ramus marginalis mandibularis
- Ramus cervicalis

The branching of the plexus is variable.

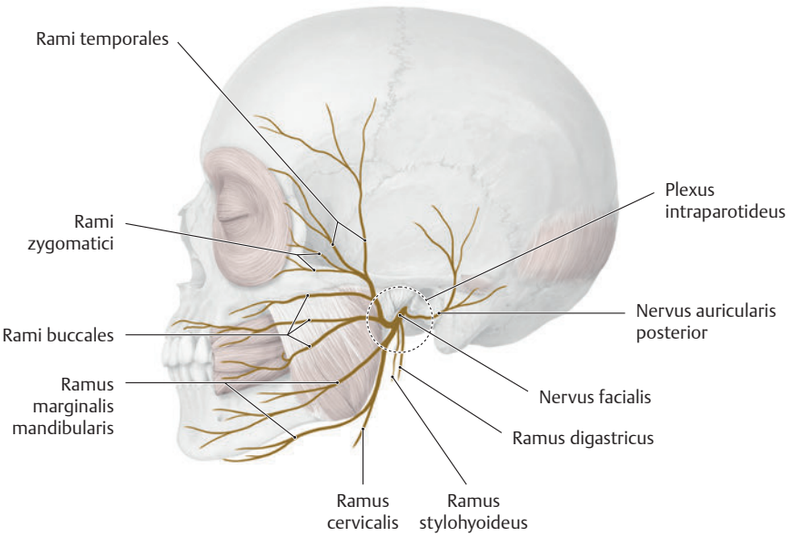
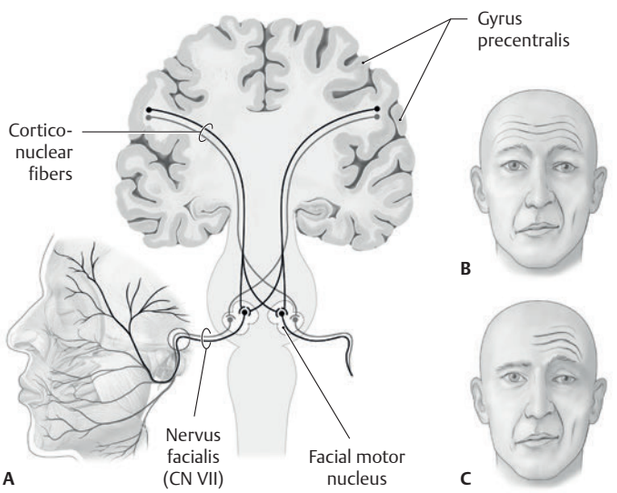


Fig. 4.89 **Facial paralysis**

A Upper motor neurons in the primary somatomotor cortex (gyrus precentralis) descend to the cell bodies of lower motor neurons in the nucleus nervi facialis. The axons of these lower motor neurons innervate the muscles derived from the second arcus pharyngeus. The nucleus nervi facialis has a "bipartite" structure: its cranial (upper) part supplies the muscles of the calvaria and rima palpebrarum, and its caudal (lower) part supplies the muscles of the lower face. The cranial part of the nucleus receives bilateral innervation (from upper motor neurons in both hemispheres). The caudal part receives contralateral innervation (from cortical neurons on the other side).

B Central (supranuclear) paralysis: Loss of upper motor neurons (shown here for the left hemisphere) causes contralateral paralysis in the lower half of the face but no paralysis in the upper half. For example, the patient's mouth will sag on the right (contralateral paralysis of lower muscles), but the ability to wrinkle the forehead and close the eyes is intact.

C Peripheral (infranuclear) paralysis: Loss of lower motor neurons (shown here for right truncus encephali) causes complete ipsilateral paralysis. For example, the whole right side of the face is paralyzed. Depending on the site of the lesion, additional deficits may be present (decreased lacrimation or salivation, loss of taste sensation in the presulcal (anterior two thirds) tongue).



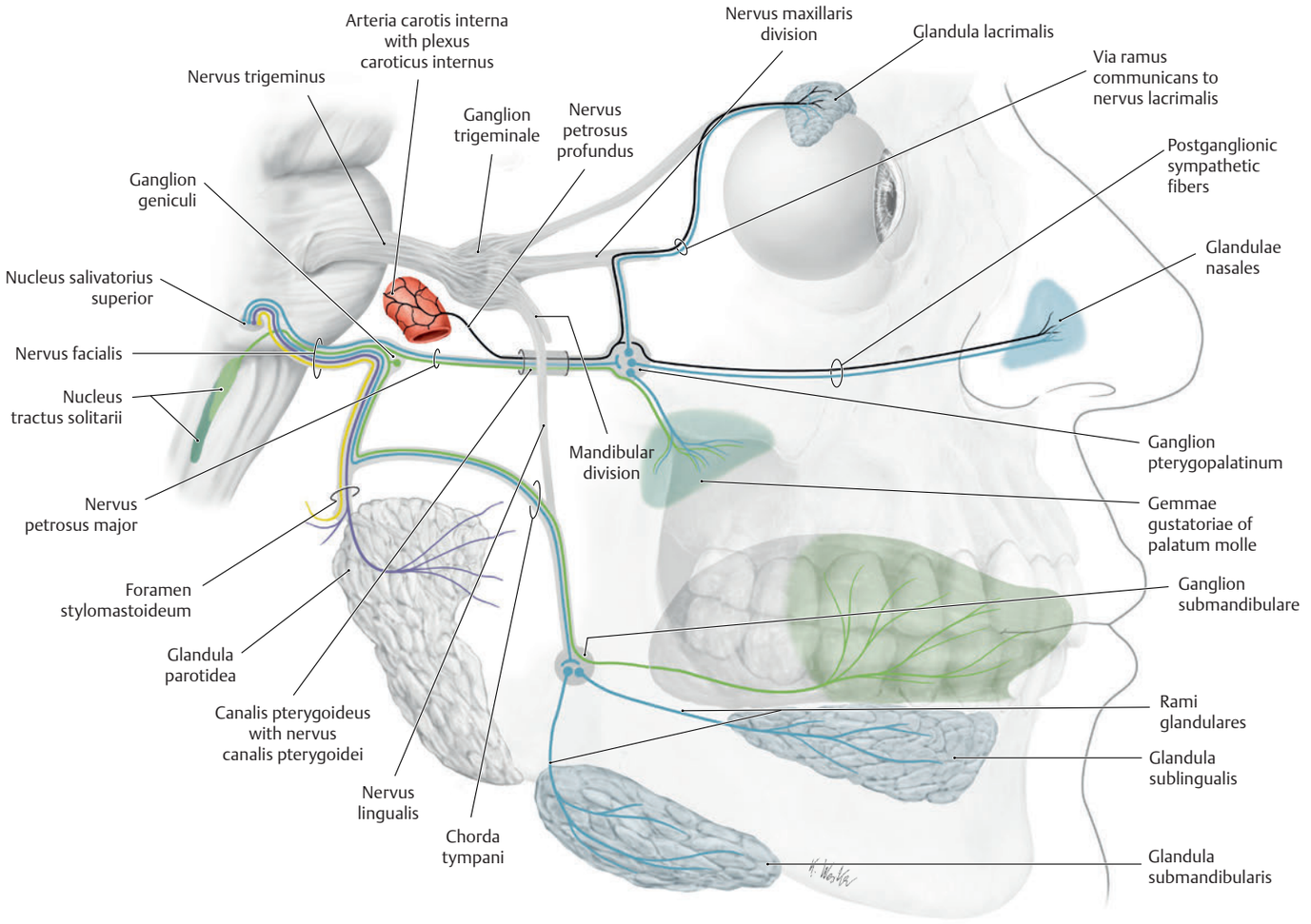
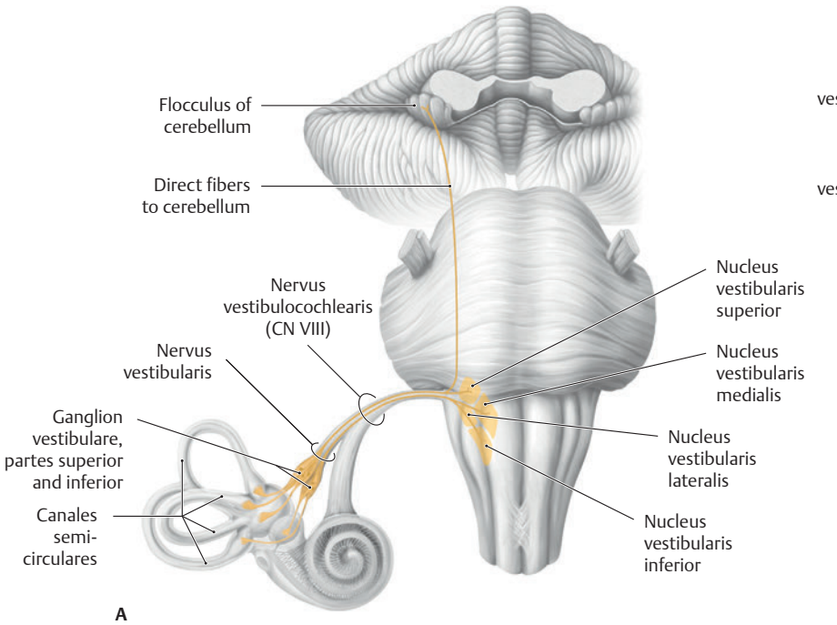


Fig. 4.90 **Nervus facialis ganglia**
Autonomic and taste fibers often travel with sensory fibers from other nerves to reach their targets. Parasympathetic and taste fibers leave the nervus facialis via two branches: the nervus petrosus major and the chorda tympani.

- **Nervus petrosus major:** Preganglionic parasympathetic and taste fibers from the ganglion geniculi course in the canalis nervi petrosi majoris. They are joined by the nervus petrosus profundus, which conveys postganglionic sympathetic fibers from the ganglion cervicale superius (via the plexus caroticus internus). The nervi petrosi major and profundus combine to form the nervus canalis pterygoidei (vidian nerve), which conveys sympathetic, parasympathetic, and taste fibers to the ganglion pterygopalatinum (only parasympathetics will synapse at the ganglion; all other fiber types pass through without synapsing). Branches of CN V_2 then distribute the fibers to their targets:
  - **Glandula lacrimalis:** Autonomic fibers (sympathetic and parasympathetic) run with branches of CN V_2 (nervus zygomaticus and ramus zygomaticotemporalis) to a ramus communicans, which conveys them to the nervus lacrimalis (CN V_1) and thus to the glandula lacrimalis.
  - **Glandulae salivariae minores of the cavitates nasi and oris:** Autonomic fibers run with branches of CN V_2 to the small glandulae in the mucosa of the cavitas nasi, sinus maxillares, and tonsillae palatinae.
  - **Taste:** Taste fibers run with branches of CN V_2 to the palatum molle.
- **Chorda tympani:** Preganglionic parasympathetic and taste fibers course through the chorda tympani. They emerge from the fissura petrotympanica and combine with the nervus lingualis (CN V_3) in the fossa infratemporalis. They are conveyed to the ganglion submandibulare by the nervus lingualis, and from there, postganglionic branches travel to their targets via branches of CN V_3.
  - **Glandulae submandibularis and sublingualis:** Postganglionic parasympathetic fibers run with branches of CN V_3 to the glands.
  - **Gemmae gustatoriae of tongue:** The gemmae gustatoriae on the presulcal portion (anterior two thirds) of the tongue receive taste fibers from the chorda tympani via the nervus lingualis (CN V_3). *Note:* The postsulcal portion (posterior one third) of the tongue and the pars oralis pharyngis receive taste fibers from CN IX. The radix linguae and epiglottis receive taste fibers from CN X.

Note: The **nervus petrosus minor** runs in the canalis nervi petrosi minoris roughly parallel to the nervus petrosus major. The nervus petrosus minor conveys preganglionic parasympathetic fibers from the plexus tympanicus (CN IX) to the ganglion oticum. These fibers innervate the glandulae parotidea, buccales, and labiales inferiores, with postganglionic fibers distributed via branches of CN V_3.

CN VIII: Nervus Vestibulocochlearis



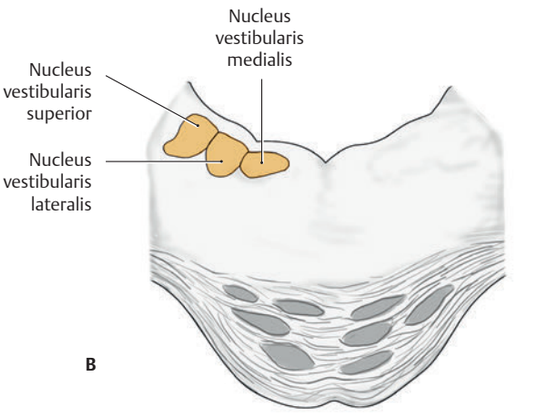
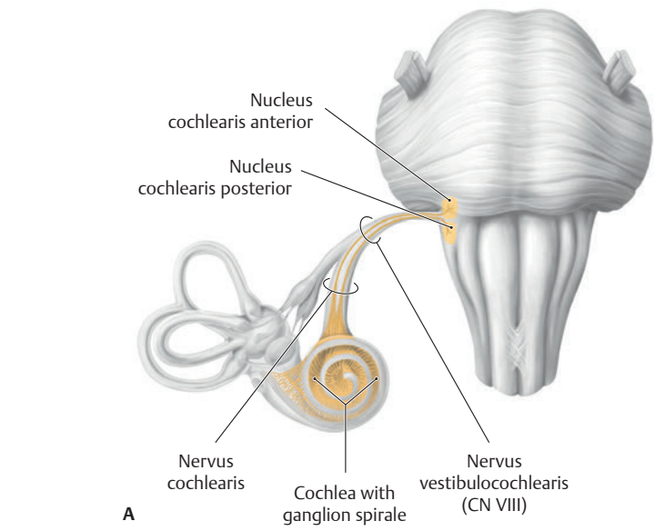


Fig. 4.91 **Vestibular root and nuclei**
A Anterior view of the medulla oblongata and pons. **B** Cross-section through the upper medulla oblongata.



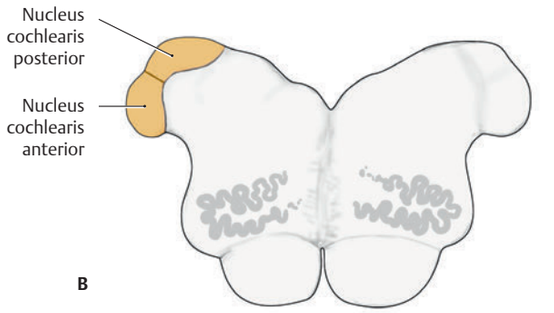


Fig. 4.92 **Cochlear root and nuclei**
A Anterior view of the medulla oblongata and pons. **B** Cross-section through the upper medulla oblongata.

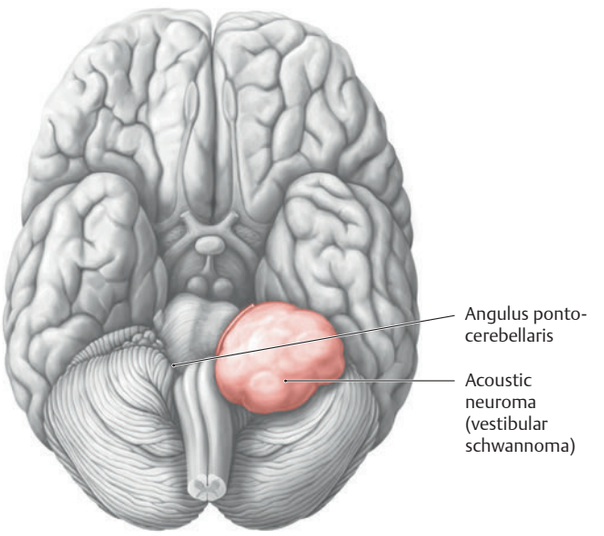


Fig. 4.93 **Acoustic neuroma in the angulus pontocerebellaris**
Acoustic neuromas (more accurately, vestibular schwannomas) are benign tumors of the angulus pontocerebellaris arising from the Schwann cells of the nervus vestibularis of CN VIII. As they grow, they compress and displace the adjacent structures and cause slowly progressive hearing loss and gait ataxia. Large tumors can impair the egress of CSF from the 4th ventriculus, causing hydrocephalus and symptomatic intracranial hypertension (vomiting, impairment of consciousness).

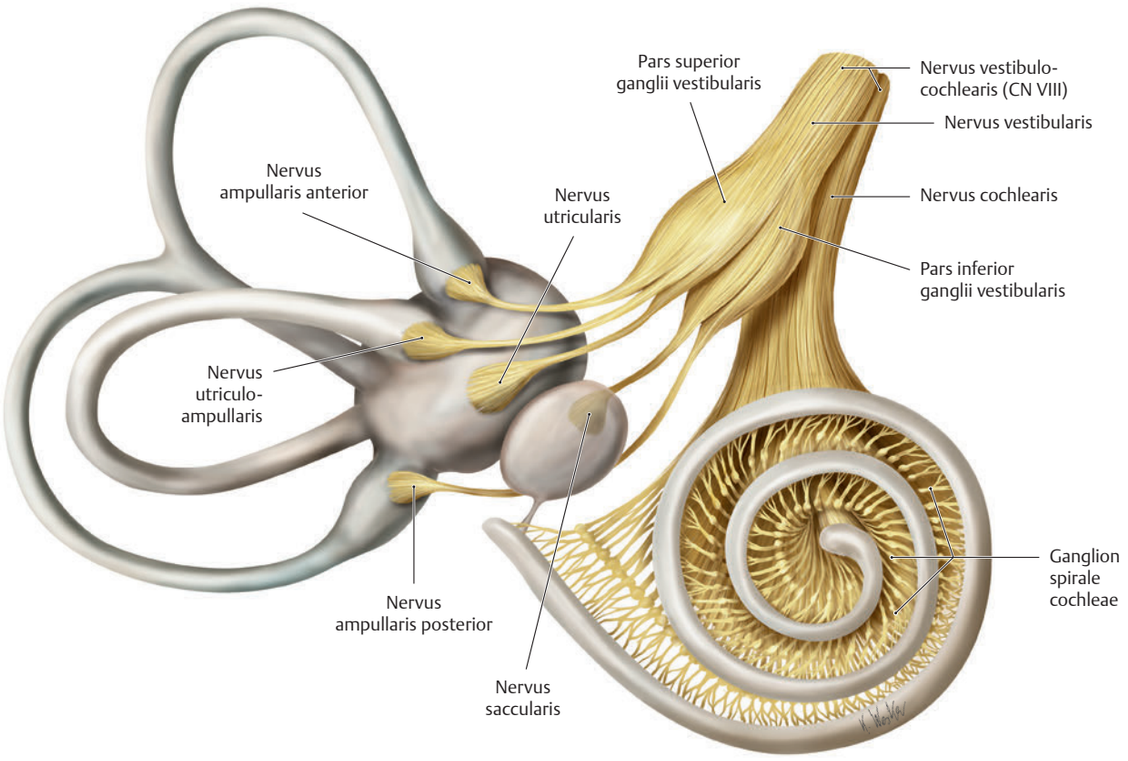
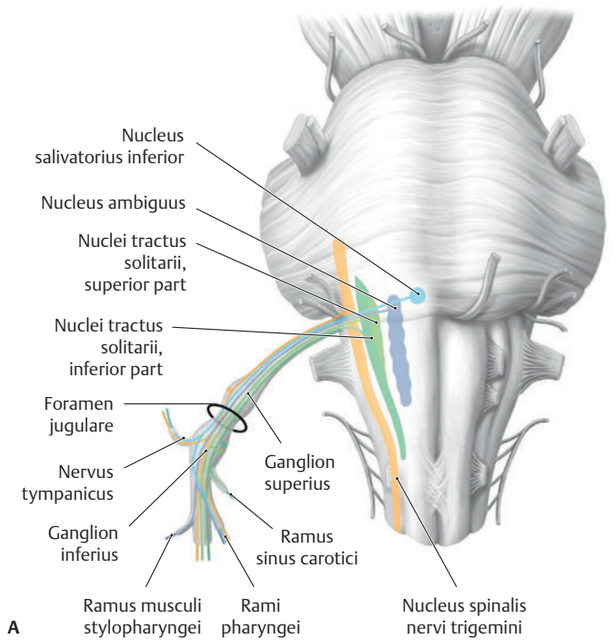


Fig. 4.94 **Nervus vestibulocochlearis (CN VIII)**
The nervus vestibulocochlearis consists of two parts. The nervus vestibularis conveys afferent impulses from the vestibular apparatus (balance). The nervus cochlearis conveys afferent impulses from the auditory apparatus (hearing).

Table 4.26 **Nervus vestibulocochlearis (CN VIII)**

Nuclei, ganglia, and fiber distribution		
Special somatic afferent (orange)**:** Special somatic sensory neurons convey sensory fibers from the vestibular apparatus (balance) and auditory apparatus (hearing). Both parts of the nerve contain first-order bipolar sensory neurons.		
Neurons	**Nervus vestibulus**	**Nervus vestibularis**
Peripheral processes	In the sensory cells of the canales semicirculares, the sacculus, and the utriculus.	In the hair cells of the organum spirale.
Cell bodies	**Ganglion vestibulare** • Pars inferior: Peripheral processes from sacculus and canalis semicircularis posterior. • Pars superior: Peripheral processes from canales semicirculares anterior and lateralis and utriculus.	**Ganglion spirale cochleae.** The peripheral processes from the neurons in these myriad ganglia radiate outward to receive sensory input from the spiral modiolus.
Central processes (axons)	To four **nuclei vestibulares** in the medulla oblongata (floor of the fossa rhomboidea). A few pass directly to the cerebellum via the pedunculus cerebellaris inferior.	To two **nuclei cochleares** lateral to the nuclei vestibulares.
Nuclei	Nuclei vestibulares superior, lateralis, medialis, and inferior.	Nuclei cochleares anterior and posterior.
Lesions	Dizziness and vertigo.	Hearing loss (ranging to deafness).
Course		
The nervi vestibularis and cochlearis unite in the meatus acusticus internus to form the nervus vestibulocochlearis, which is covered by a common connective tissue sheath. The nerve emerges from the meatus acusticus internus on the medial surface of the pars petrosa ossis temporalis and enters the brainstem at the level of the pontomedullary junction, in particular at the angulus pontocerebellaris.		

CN IX: Nervus Glossopharyngeus



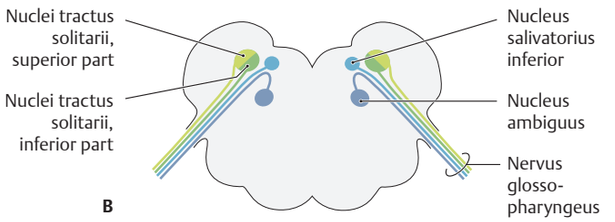


Fig. 4.95 **Glossopharyngeal nerve nuclei**
A Anterior view of truncus encephali. **B** Cross-section through the medulla oblongata.

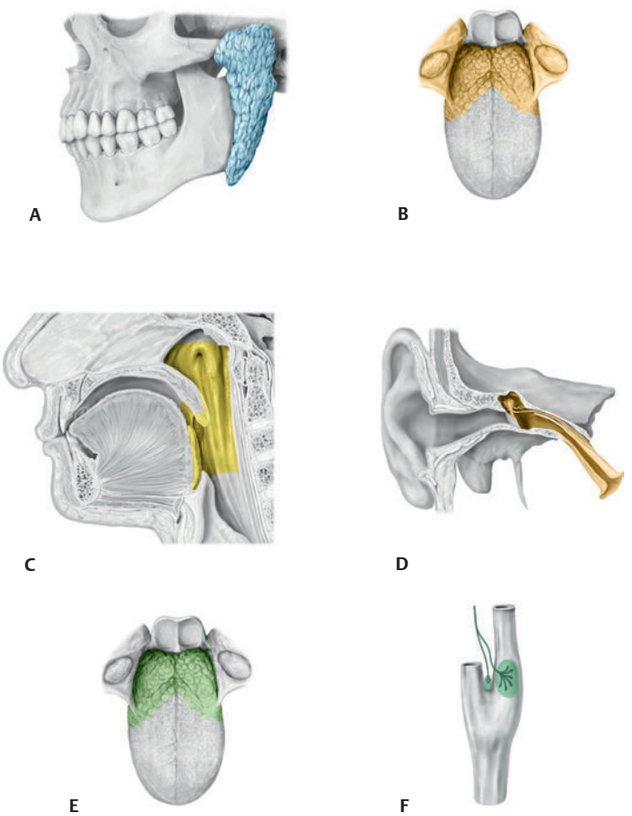


Fig. 4.96 **Distribution of CN IX fibers**

Table 4.27 **Nervus glossopharyngeus (CN IX)**	
Nuclei, ganglia, and fiber distribution	
Branchiomotor (purple)	
Nucleus ambiguus	Lower motor neurons innervate the muscles derived from the 3rd, 4th, and 6th arcus pharyngei via CN IX, X, and XI. • CN IX innervates the derivative of the 3rd arcus pharyngeus (musculus stylopharyngeus)
Parasympathetic (blue)	
Nucleus salivatorius inferior	Preganglionic neurons synapse in the **ganglion oticum**.
	Postganglionic neurons innervate: • Glandula parotidea (**Fig. 4.96A**) • Glanduale buccales • Glandulae labiales inferiores
General somatic afferent (yellow)	
Nucleus spinalis nervi trigemini	First-order pseudounipolar cells in the **ganglion superius** of CN IX innervate: • Pars nasalis pharyngis (inferior torus tubarius), pars oralis pharyngis, postsulcal tongue, tonsillae palatinae, and uvula (**Fig. 4.96C**). These fibers include the afferent limb of the gag reflex. • Cavitas tympanica and tuba auditiva (**Fig. 4.96D**).
Viscerosensory (green)	
First-order pseudounipolar cells in the **ganglion inferius** relay taste and visceral sensation to the **nuclei tractus solitarii**. This nuclear complex consists of a superior part (taste) and inferior part (general visceral sensation).	
Nuclei tractus solitarii	Taste (**Fig. 4.96E**): Special viscerosensory fibers from the postsulcal tongue synapse in the **superior part**.
	Visceral sensation (**Fig. 4.96F**): General viscero-sensory fibers from the glomus caroticum (chemoreceptors) and sinus caroticus (pressure receptors) synapse in the **inferior part**.
Course	
The nervus glossopharyngeus arises from the medulla oblongata and exits the skull by passing through the foramen jugulare. It has two sensory ganglia with first-order pseudounipolar sensory cells: the ganglion superius (somatosensory) is within the cavitas cranii, and the ganglion inferius (viscerosensory) is distal to the foramen jugulare.	
Lesions	
Isolated CN IX lesions are rare. Lesions tend to occur during basal skull fractures, which disrupt the foramen jugulare. Such injuries would affect CN IX, X, and XI.	

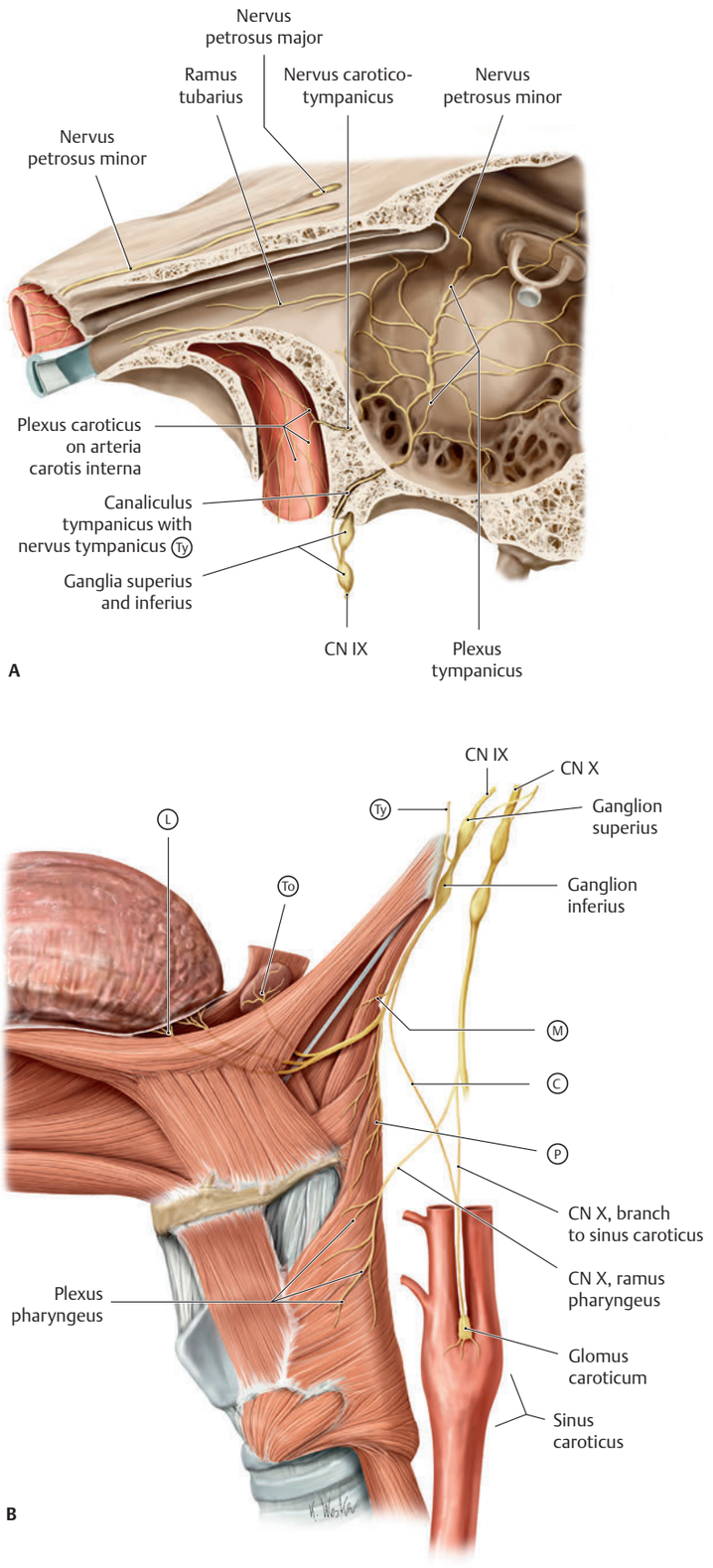


Fig. 4.97 **Glossopharyngeal nerve branches**
A Left anterolateral view of opened cavitas tympani. **B** Left lateral view.

Table 4.28 **Nervus glossopharyngealis branches**

Ⓣy Nervus tympanicus

Somatosensory and preganglionic parasympathetic fibers branch at the ganglion inferius and travel through the canaliculus tympanicus as the nervus tympanicus.

- **Plexus tympanicus:** The nervus tympanicus combines with postganglionic sympathetic fibers from the ganglion cervicale superius (via plexus caroticus and nervi caroticotympanici) and branches to form the plexus tympanicus. This plexus provides general somatosensory innervation to the cavitas tympani, tuba auditiva, and cellulae mastoideae.
- **Nervus petrosus minor:** The preganglionic parasympathetic fibers in the plexus tympanicus are reconstituted as the nervus petrosus minor, which runs in the canalis nervi petrosi minoris to synapse in the ganglion oticum.
- **Ganglion oticum:** The postganglionic parasympathetic fibers innervate the glandulae parotideus, buccales, and labiales inferiores by traveling with branches of CN V_3.

Ⓒ Ramus sinus carotici

General viscerosensory fibers from the sinus caroticus (pressure receptors) and glomus caroticum (chemoreceptors) ascend on the arteria carotis interna to join CN IX or X on their way to the inferior part of the nuclei tractus solitarii.

Ⓟ Rami pharyngei

The **plexus pharyngeus** consists of general somatosensory fibers (from CN IX), sympathetic fibers (from the truncus sympathicus), and motor fibers (from CN X).

- CN IX receives sensory fibers from the mucosa of the partes nasalis and oralis pharyngis via the plexus pharyngeus.

Ⓜ Ramus musculi stylopharyngei

The branchiomotor fibers in CN IX innervate the derivative of the 3rd arcus pharyngeus, the **musculus stylopharyngeus**.

Ⓣo Rami tonsillares

General somatosensory fibers from the tonsillae palatinae and mucosa of the pars oralis pharyngis.

Ⓛ Rami linguales

General somatosensory and special viscerosensory (taste) fibers from the postsulcal tongue (posterior one third).

CN X: Nervus Vagus

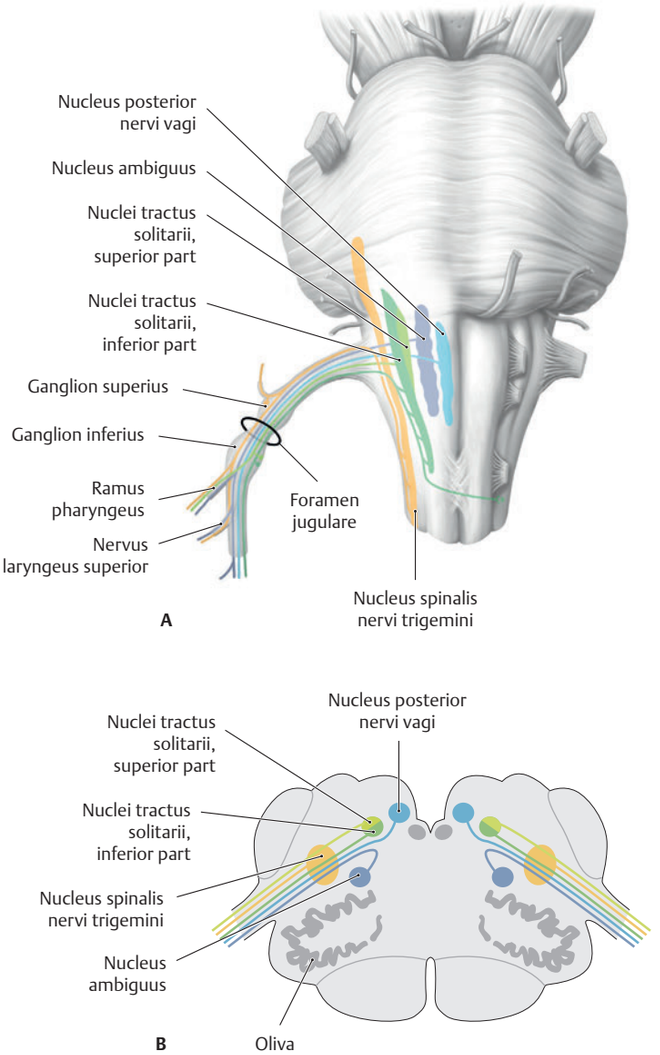


Fig. 4.98 **Nuclei nervi vagi**
A Anterior view of medulla oblongata. **B** Cross-section through the medulla oblongata.
The nervus vagus has the most extensive distribution of all the nervi craniales (L. *vagus* = vagabond). Parasympathetic fibers descend into the thorax and abdomen. These fibers form autonomic plexuses with postganglionic sympathetic fibers (from the truncus sympathicus and abdominal ganglia). The plexuses extend along organs and blood vessels and provide motor innervation to the thoracic and abdominal viscera. General viscerosensory fibers ascend via CN X to the inferior part of the nuclei tractus solitarii.

Table 4.29 **Nervus vagus (CN X)**

Nuclei, ganglia, and fiber distribution	
Branchiomotor (purple)	
Nucleus ambiguus	Lower motor neurons innervate the muscles derived from the 3rd, 4th, and 6th arcus pharyngei via CN IX, X, and XI. CN X innervates the derivatives of the 4th and 6th arcus pharyngei: • Musculi pharyngis (musculi constrictores pharyngis) • Muscles of the palatum molle (musculus levator veli palatini, musculus uvulae, musculus palatoglossus, musculus palatopharyngeus) • Intrinsic musculi laryngis
Parasympathetic (blue)	
Nucleus posterior nervi vagi	Preganglionic neurons synapse in small, unnamed ganglia close to target structures.
	Postganglionic neurons innervate: • Smooth muscles and glands of thoracic and abdominal viscera (**Fig. 4.100G**)
General somatic afferent (yellow)	
Nucleus spinalis nervi trigemini	First-order pseudounipolar cells in the **ganglion superius** innervate: • Dura mater of the fossa cranii posterior (**Fig. 4.100F**) • Meatus acusticus externa, and lateral membrana tympanica (**Fig. 4.100C**) • Mucosa of the partes oralis and laryngea pharyngis
Viscerosensory (green)	
First-order pseudounipolar cells in the **ganglion inferius** relay taste and visceral sensation to the **nuclei tractus solitarii**. This nuclear complex consists of a superior part (taste) and inferior part (general visceral sensation).	
Nuclei tractus solitarii	Taste (**Fig. 4.100D**): Fibers from the epiglottis and the radix linguae are conveyed to the **superior part** of the nuclei tractus solitarii.
	Visceral sensation (**Fig. 4.100G**): Fibers are relayed to the **inferior part** of the nuclei tractus solitarii from: • Mucosa of the pars laryngea pharyngis and larynx (**Fig. 4.100A**) • Arcus aortae (pressure receptors) and corpus paraaorticum (chemoreceptors) (**Fig. 4.100E**) • Thoracic and abdominal viscera (**Fig. 4.100G**)
Course	
The nervus vagus arises from the medulla oblongata and emerges from the skull via the foramen jugulare. It has two sensory ganglia with first-order pseudounipolar cells: the ganglion superius (somatosensory) is within the cavitas cranii, and the ganglion inferius (viscerosensory) is distal to the foramen jugulare.	
Lesions	
The nervus laryngeus recurrens supplies parasympathetic innervation to the intrinsic musculi laryngis (except the musculus cricothyroideus). This includes the musculus cricoarytenoideus posterior, the only muscle that abducts the plicae vocales. Unilateral lesions of this nerve cause hoarseness; bilateral destruction leads to respiratory distress (dyspnea).	

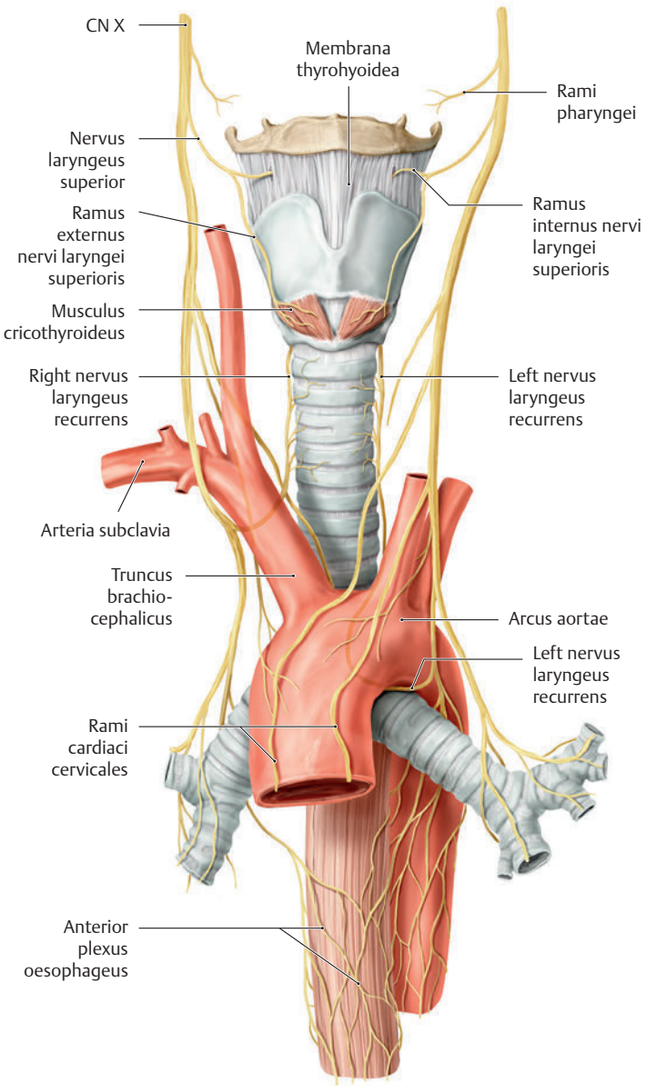


Fig. 4.99 **Nervus vagus branches in the neck**
Anterior view.

Table 4.30 **Nervus vagus branches**

Ramus meningeus
General somatosensory fibers from the dura mater of the fossa cranii posterior.
Ramus auricularis
General somatosensory fibers from auris externa (auricula, porus acusticus externus, and part of lateral side of membrana tympanica).
Ramus pharyngeus
The **plexus pharyngeus** consists of general somatosensory fibers (from CN IX), sympathetic fibers (from the truncus sympathicus), and motor fibers (from CN X). • CN X conveys branchiomotor fibers to the musculi pharyngis.
Carotid branch
General viscerosensory fibers from the glomus caroticum (chemoreceptors) ascend on the arteria carotis interna to join CN IX or X on their way to the inferior part of the nuclei tractus solitarii.
Nervus laryngeus superior
Combines with a sympathetic branch from the ganglion cervicale superius and divides into: • **Ramus internus:** Sensory fibers from the mucosa of the pars laryngea pharyngis, larynx, and radix linguae • **Ramus externus:** Parasympathetic motor innervation to the musculus cricothyroideus.
Nervus laryngeus recurrens
The nervus laryngeus recurrens is asymmetrical: • Right nervus laryngeus recurrens: Recurs behind the right arteria subclavia. • Left nervus laryngeus recurrens: Recurs behind the arcus aortae. Ascends between the trachea and oesophagus. The nervi laryngei recurrentes supply: • Motor innervation to the musculi laryngis (except the musculus cricothyreoideus). • Viscerosensory innervation to the laryngeal mucosa.
Branches to the thorax and abdomen
The nervus vagus also conveys parasympathetic and general viscerosensory fibers from the plexus cardiacus, pulmonalis, oesophageus, coeliacus, renalis, hepaticus, and gastricus (**Fig. 4.100G**)

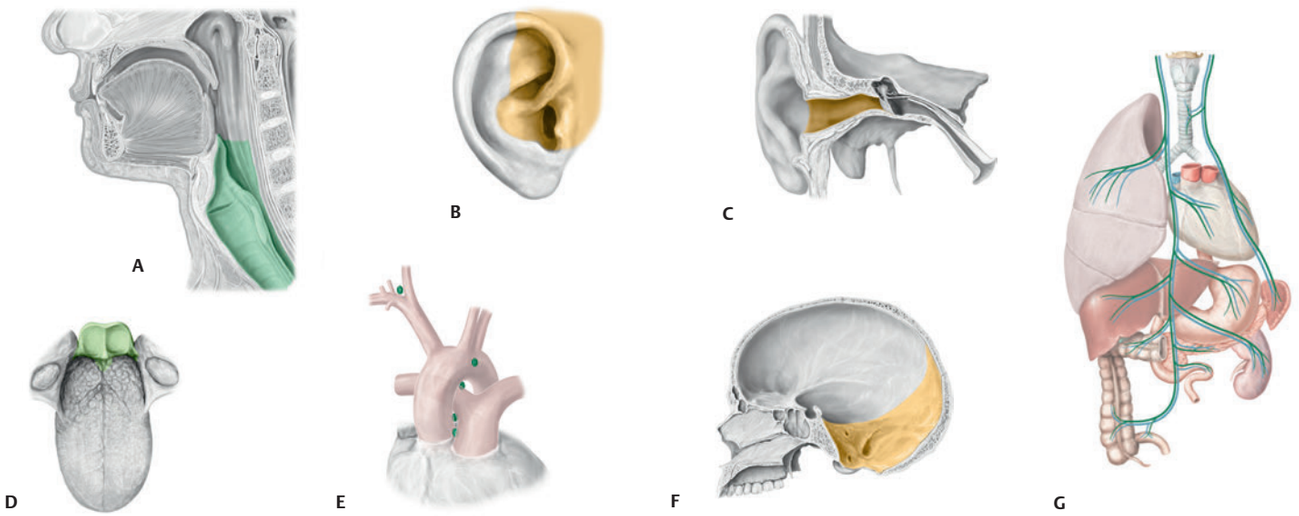


Fig. 4.100 **Distribution of the nervus vagus (CN X)**

CN XI & XII: Nervi Accessorius & Hypoglossus

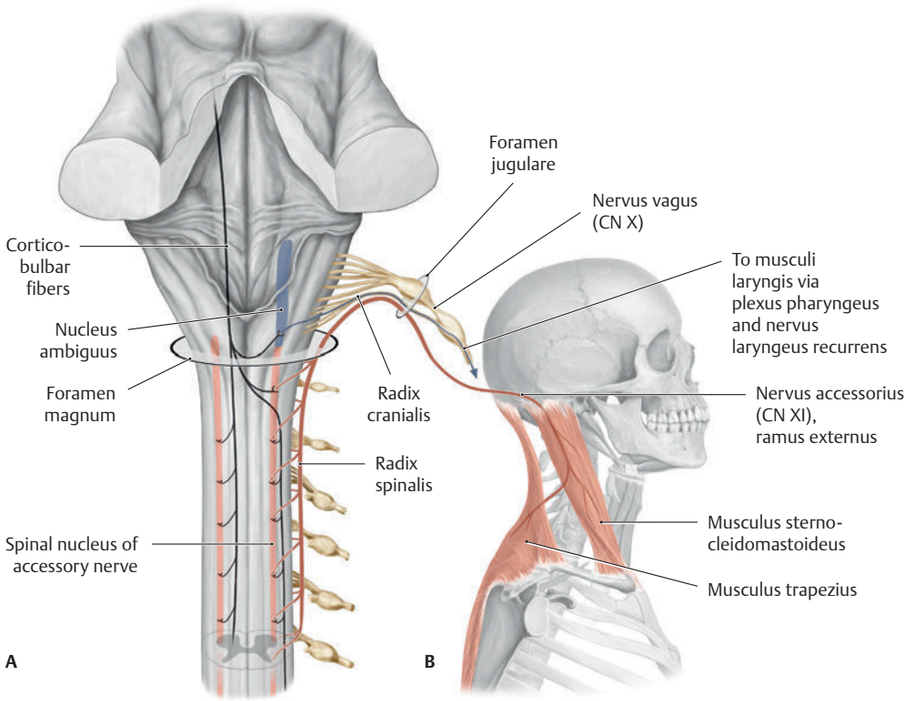


Fig. 4.101 **Nervus accessorius**
A Posterior view of truncus encephali. **B** Right lateral view of musculi sternocleidomastoideus and trapezius. (*Note:* For didactic reasons, the right muscles are displayed though they are innervated by the right nuclei nervorum cranialium.)

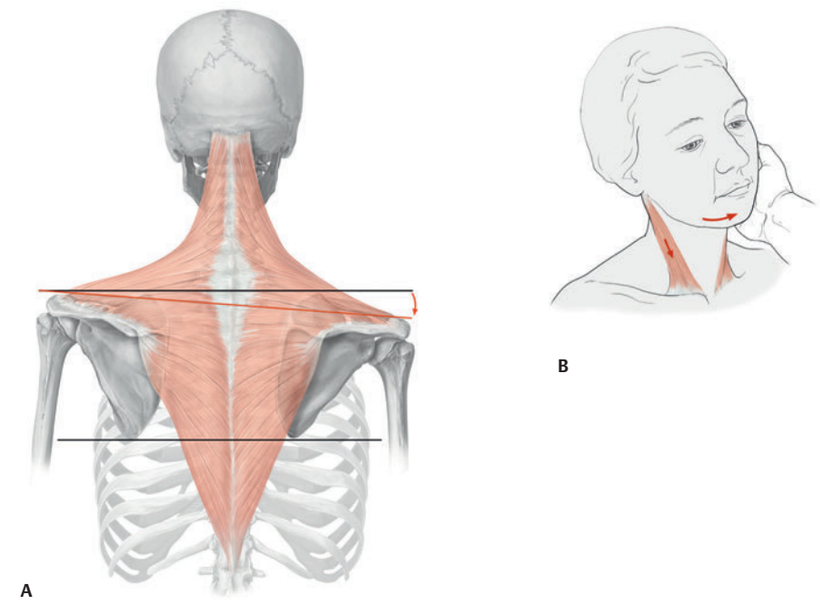


Fig. 4.102 **Accessory nerve lesions**
Accessory nerve lesions cause partial paralysis of the musculus trapezius and complete (flaccid) paralysis of the musculus sternocleidomastoideus (see **Table 4.28**). Both lesions shown here are unilateral (right side). **A** Posterior view. Partial paralysis of the musculus trapezius causes drooping of the shoulder on the affected side. **B** Right anterolateral view. Flaccid paralysis of the musculus sternocleidomastoideus causes torticollis (wry neck).

Table 4.31 **Nervus accessorius (CN XI)**

Nuclei, ganglia, and fiber distribution	
Branchiomotor (purple)	
Nucleus ambiguus	Lower motor neurons innervate the muscles derived from the 3rd, 4th, and 6th arcus pharyngei via CN IX, X, and XI. • CN XI innervates the musculi laryngis (except musculus cricoarytenoideus) with motor fibers being distributed by branches of CN X.
General somatomotor (red)	
Spinal nucleus of CN XI	Lower motor neurons in the lateral part of the cornu anterius of C2–C6 medulla spinalis segments innervate: • Musculus trapezius (upper part). • Musculus sternocleidomastoideus.

Course

CN XI arises and courses in two parts that unite briefly distal to the foramen jugularis:

Radix cranialis: Branchiomotor fibers emerge from the medulla oblongata and pass through the foramen jugulare. They briefly unite with the radix spinalis before joining CN X at the ganglion inferius. CN X distributes the branchiomotor fibers via the plexus pharyngeus and the nervi laryngei superior and recurrens.

Radix spinalis: General somatomotor fibers emerge as rootlets from the medulla spinalis. They unite and ascend through the foramen magnum. The radix spinalis then passes through the foramen jugulare, courses briefly with the radix cranialis, and then descends to innervate the musculi sternocleidomastoideus and trapezius.

Lesions

The musculus sternocleidomastoideus is exclusively innervated by CN XI, and the lower portions of the musculus trapezius may be innervated by C3–C5. Nervus accessorius lesions therefore cause complete (flaccid) musculus sternocleidomastoideus paralysis but only partial trapezius paralysis.

Musculus trapezius paralysis: Unilateral lesions may occur during operations in the neck (e.g., lymph node biopsies), causing:
- Drooping of the shoulder on the affected side.
- Difficulty raising the arm above the horizontal.

Musculus sternocleidomastoideus paralysis:
- Unilateral lesions: Flaccid paralysis causes torticollis (wry neck, i.e., difficulty turning the head to the opposite side).
- Bilateral lesions: Difficulty holding the head upright.

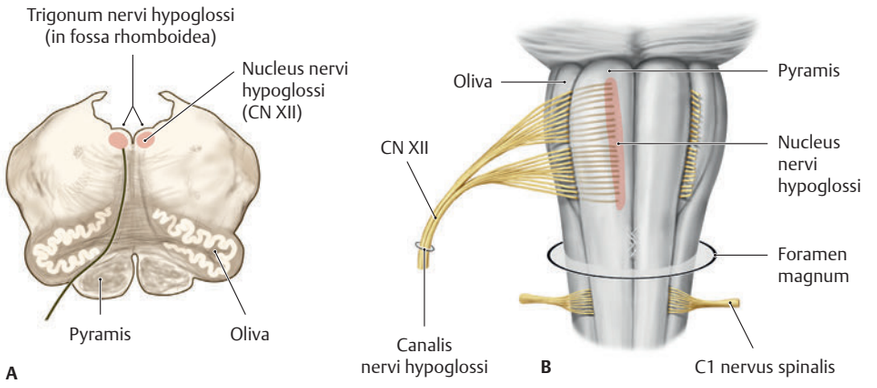


Fig. 4.103 **Nuclei nervi hypoglossi**
The nucleus nervi hypoglossi is located in the floor of the fossa rhomboidea. Rootlets emerge between the pyramis and the oliva. **A** Cross-section through the medulla oblongata. The proximity of the nuclei to the midline causes extensive lesions to involve both nuclei. **B** Anterior view of medulla oblongata.

Table 4.32 **Nervus hypoglossus (CN XII)**

Nuclei, ganglia, and fiber distribution	
General somatomotor (red)	
Nucleus of CN XII	Lower motor neurons innervate: • Extrinsic lingual muscles (except musculus palatoglossus). • Intrinsic lingual muscles.
Course	
The nervus hypoglossus emerges from the medulla oblongata as rootlets between the oliva and pyramis. These rootlets combine into CN XII, which courses through the canalis nervi hypoglossi. CN XII enters the radix linguae superior to the os hyoideum and lateral to the musculus hyoglossus. • C1 motor fibers from the plexus cervicalis travel with the nervus hypoglossus: some branch to form the radix superior of the ansa cervicalis (not shown), whereas others continue with CN XII to supply the musculi geniohyoideus and thyrohyoideus.	
Lesions	
Upper motor neurons innervate the lower motor neurons in the contralateral nucleus of the nervus hypoglossus. Supranuclear lesions (central hypoglossal paralysis) will therefore cause the tongue to deviate away from the affected side. Nuclear or peripheral lesions will cause the tongue to deviate toward the affected side (**Fig. 4.104C**).	

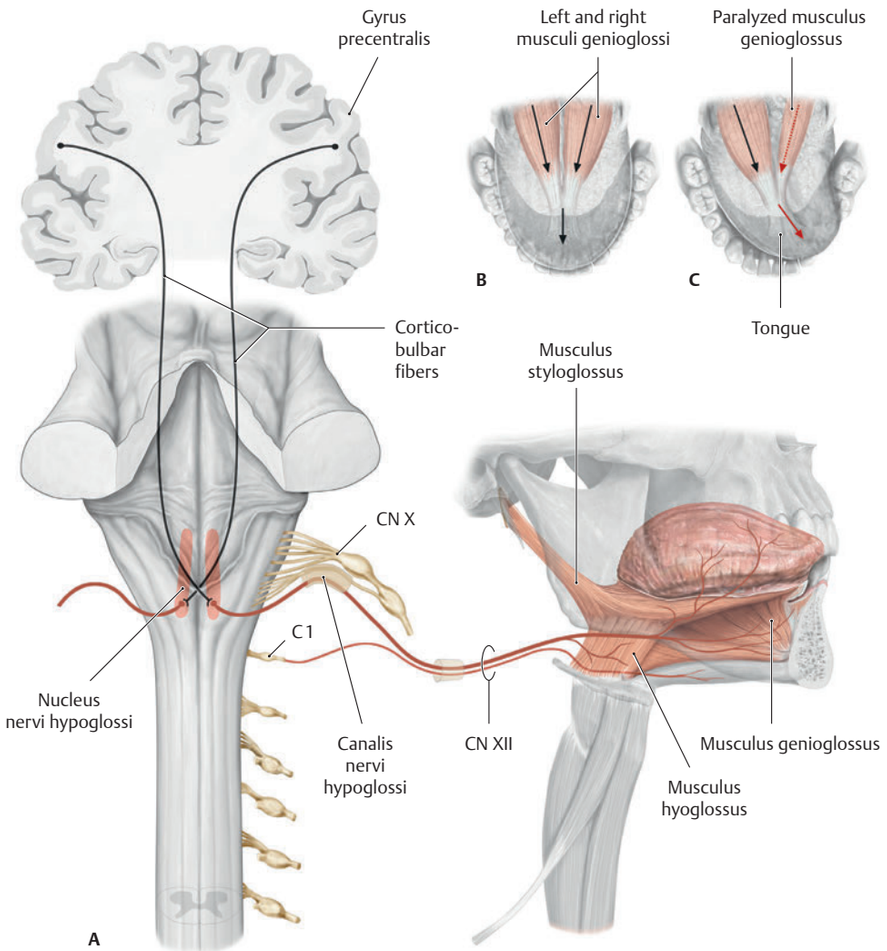
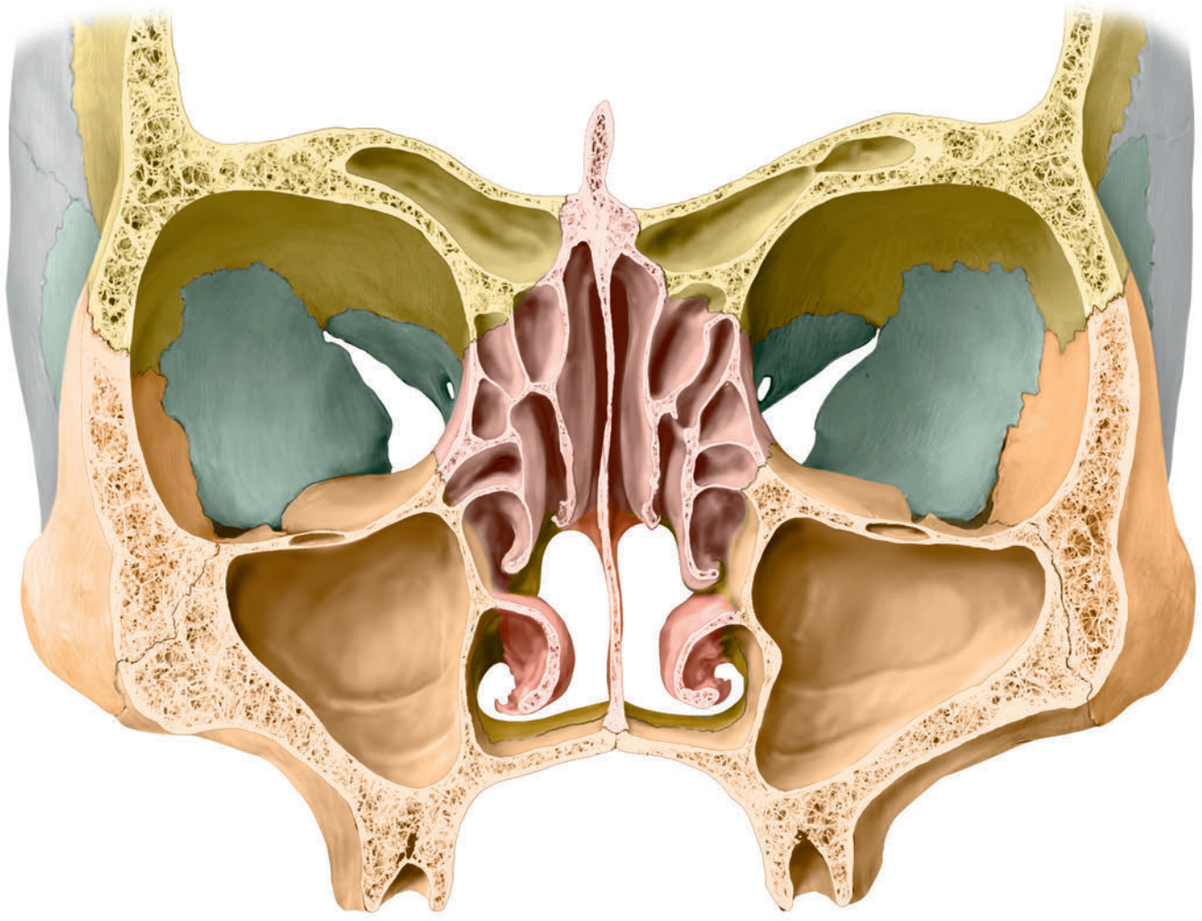


Fig. 4.104 **Nervus hypoglossus**
A Course of the nervus hypoglossus. Upper motor neurons synapse on lower motor neurons on the contralateral nucleus of the nervus hypoglossus. Supranuclear lesions will therefore cause contralateral paralysis; peripheral lesions will cause ipsilateral paralysis (same side). **B** The functional musculus genioglossus extends the tongue anteriorly. **C** Unilateral paralysis due to a peripheral lesion causes the tongue to deviate *toward* the affected side (dominance of the intact musculus genioglossus).



Regions of the Head

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Musculi Faciei

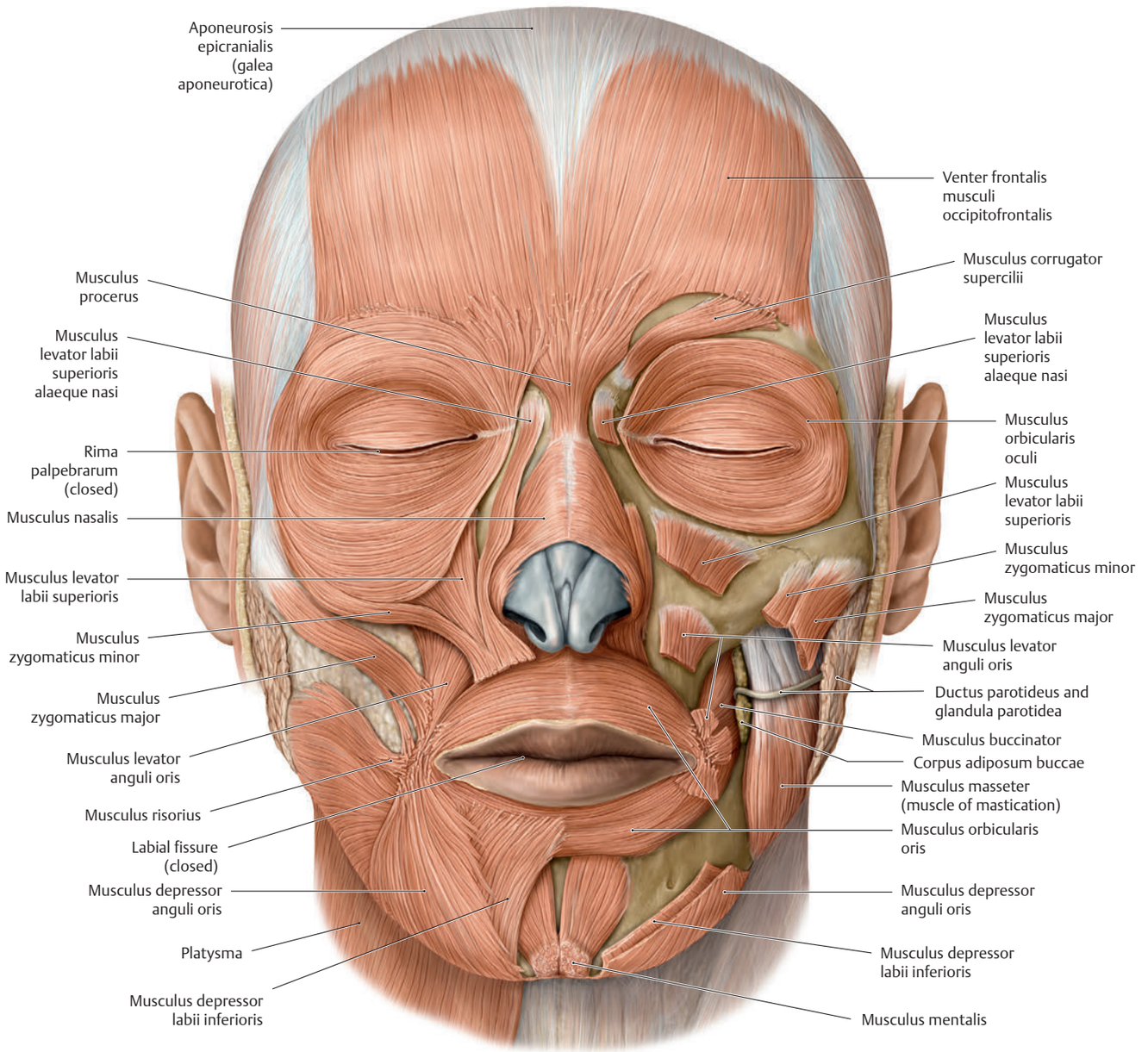


Fig. 5.1 **Superficial musculi faciei**
Anterior view. The superficial layer of muscles is shown on the right side of the face. Certain muscles have been cut on the left to expose deeper muscles. The musculi faciei are the superficial layer of muscles that arise either directly from the periosteum or from adjacent muscles and insert onto other musculi faciei or directly into the connective tissue of the skin. Because of their cutaneous attachments, the musculi faciei are able to move the facial skin (an action that may be temporarily abolished by botulinum toxin injection). They also serve a protective function (especially for the eyes) and are active during food ingestion (closing the labial fissure). The musculi faciei are innervated by branches of the nervus facialis (CN VII). As these muscles are located in the subcutaneous fat, and because the superficial body fascia is absent in the face, surgeons must be particularly careful when dissecting this region. The lack of fascia on the face and the loose connective tissue between the cutaneous attachments of the musculi faciei also means that facial lacerations, following a blow to the face for example, tend to gape widely. This necessitates careful suturing of these lacerations to approximate the edges of the wound and to prevent scarring. The loose nature of the connective tissue also provides a place for blood and fluid to accumulate, leading to swelling and bruising of the face. Such swelling may also be apparent following an inflammatory insult, such as a bee sting. The muscles of mastication lie deep to the musculi faciei. They control the movement of the mandibula and are innervated by branches of the nervus trigeminus (CN V).

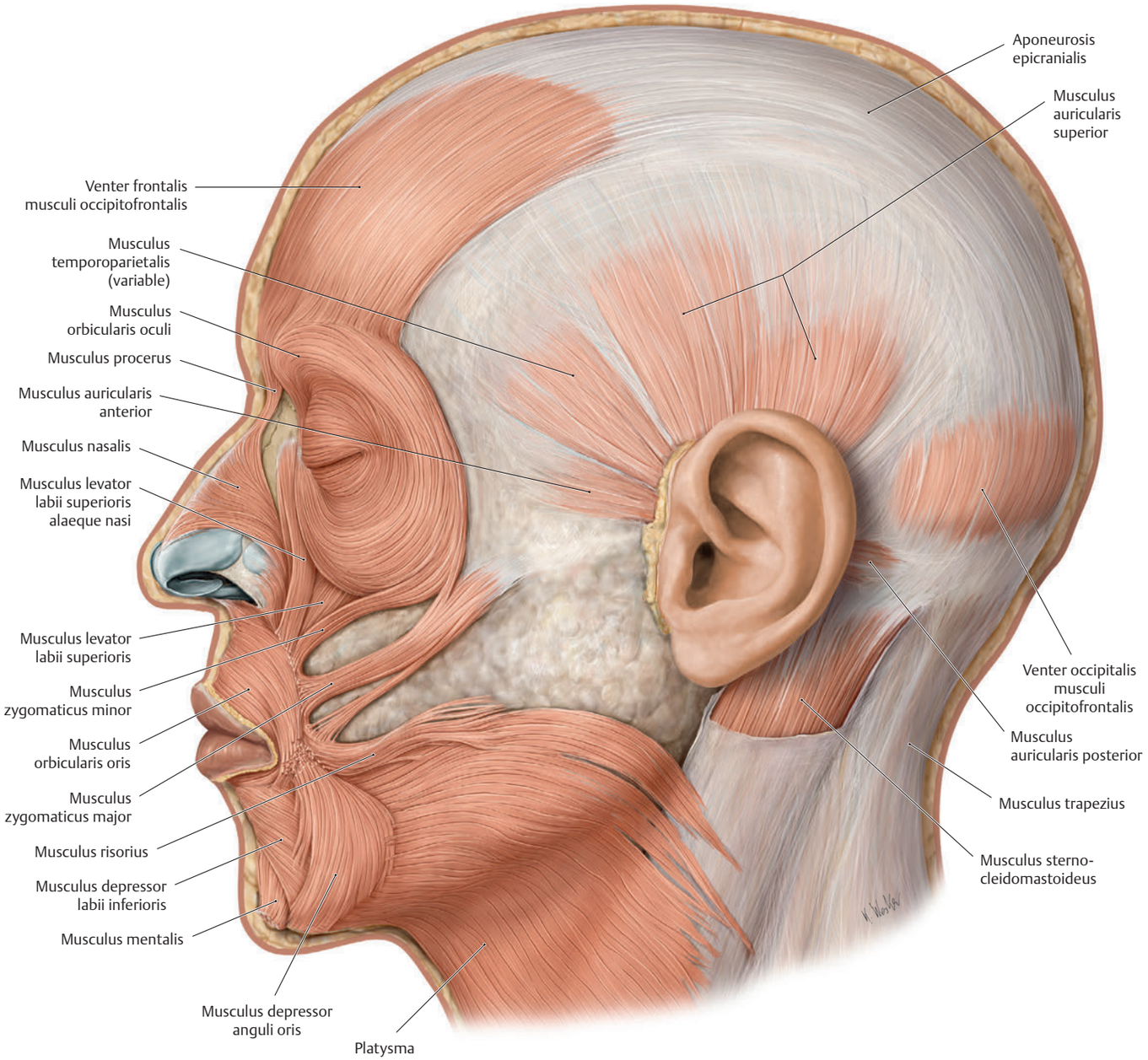


Fig. 5.2 **Superficial musculi faciei**
Lateral view. The aponeurosis epicranialis (galea aponeurotica) is a tough tendinous sheet stretching over the calvaria; it is loosely attached to the periosteum. The muscles of the calvaria that arise from the aponeurosis epicranialis (musculi temporoparietalis and occipitofrontalis) are collectively known as the "epicranial muscles." The musculus occipitofrontalis has two bellies: venter frontalis and venter occipitalis. The musculi trapezius and sternocleidomastoideus are superficial neck muscles.

Musculi Faciei: Calvaria, Ear, & Eye

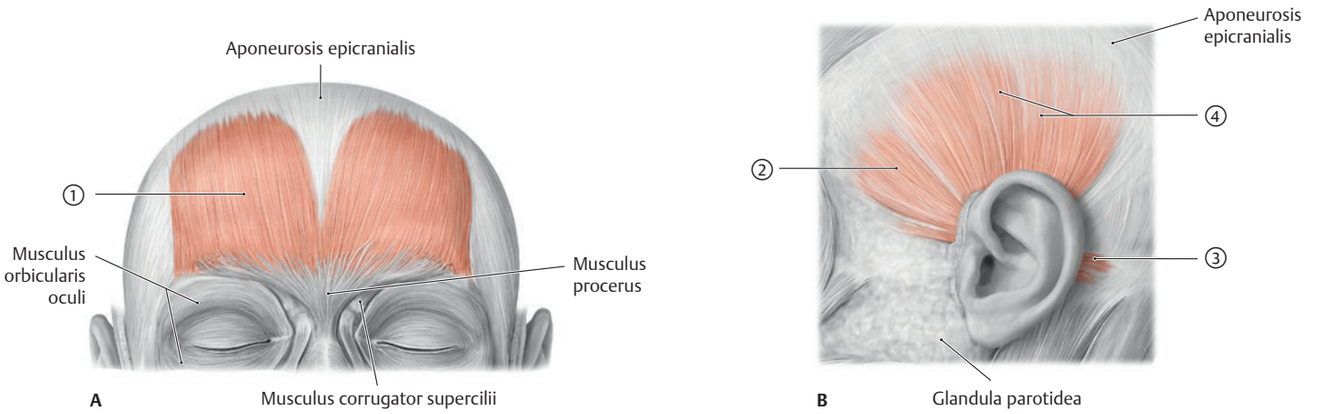


Fig. 5.3 **Musculi faciei: calvaria and ear**
A Anterior view of calvaria. **B** Left lateral view of musculi auriculares.

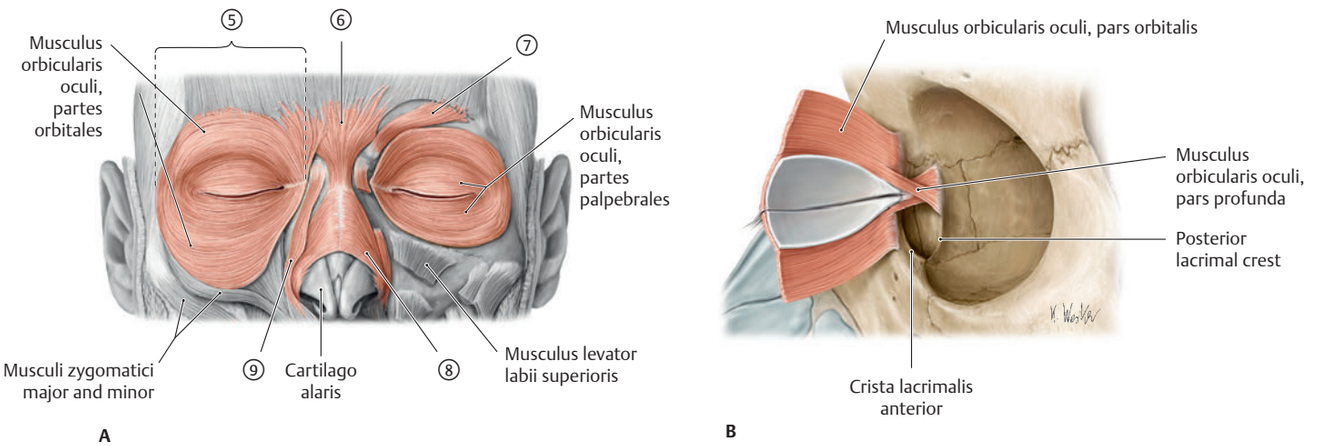


Fig. 5.4 **Musculi faciei: rima palpebrarum and nose**
A Anterior view. The most functionally important muscle of this region is the musculus orbicularis oculi, which closes the rima palpebrarum (a protective reflex against foreign matter). As the musculus orbicularis oculi closes the rima palpebrarum, it does so by closing from lateral to medial, thus spreading lacrimal secretions across the cornea (p. 243). If the action of the musculus orbicularis oculi is lost because of facial nerve paralysis, the loss of this protective reflex will be accompanied by drying of the cornea from prolonged exposure to the air. The function of the musculus orbicularis oculi is tested by asking the patient to squeeze the eyelids tightly shut. Other symptoms of facial nerve paralysis (Bell palsy) include ipsilateral drooping of the corner of the mouth, eyebrow, and lower eyelid, and the inability to smile, whistle, blow out cheeks, or wrinkle the forehead (due to paralysis of the other musculi faciei).
B The musculus orbicularis oculi has been dissected from the left orbit to the medial canthus of the eye and reflected anteriorly to demonstrate its lacrimal part (pars profunda musculi orbicularis oculi, the Horner muscle). This part of the musculus orbicularis oculi arises mainly from the crista lacrimalis posterior, and its action is a subject of debate (it may have a functional role in drainage of the saccus lacrimalis).

Fig. 5.5 **Changes of facial expression: rima palpebrarum and nose**
Anterior view.
A Musculus corrugator supercilii. **B** Musculus orbicularis oculi. **C** Musculus nasalis. **D** Musculus levator labii superioris alaeque nasi.

Table 5.1 **Musculi faciei: calvaria and ear, palbebral fissure and nose**

Muscle and parts	Origin	Insertion	I*	Main action(s)
Calvaria and ear				
① Musculus occipitofrontalis, venter frontalis	Aponeurosis epicranialis near sutura coronalis	Skin and subcutaneous tissue of eyebrows and forehead	T	Elevates eyebrows; wrinkles skin of forehead
Musculi auriculares			T	Elevate ear
② Anterior	Fascia temporalis (anterior portion)	Helix of the ear		• Pull ear superiorly and anteriorly
③ Posterior	Aponeurosis epicranialis on side of head	Upper portion of auriculus		• Elevate ear
④ Superior	Fascia temporalis	Helix of the ear	PA	• Pull ear superiorly and posteriorly
Musculus occipitofrontalis, venter occipitalis	Os occipitale (linea nuchalis suprema) and os temporale (pars petrosa)	Aponeurosis epicranialis near sutura coronalis		Pulls scalp backward
Rima palpebrarum and nose				
⑤ Musculus orbicularis oculi				Whole muscle acts as orbital sphincter (closes eyelids)
• Pars orbitalis	Medial orbital margin (os frontale and maxilla) and ligamentum palpebrale mediale	Adjacent muscles (musculus occipitofrontalis, musculus corrugator supercilii, musculus levator labii, etc.)	T/Z	• Voluntary closure of eyelids, furrowing of nose and eyebrows during squinting
• Pars palpebralis	Ligamentum palpebrale mediale	Eyelids (as lateral palpebral raphe)		• Voluntary (sleeping) and involuntary closure (blinking) of eyelids
• Pars profunda	Crista lacrimalis	Tarsi of eyelids, lateral palpebral raphe		• Pulls eyelids medially
⑥ Musculus procerus	Fascial aponeurosis of lower os nasale	Skin between eyebrows	T/Z	Pulls eyebrows medially and inferiorly (frowning)
⑦ Musculus corrugator supercilii	Bone of arcus superciliaris (medial end)	Skin above supraorbital margin	T	Acts with orbicularis oculi to pull eyebrows medially and inferiorly (during squinting)
⑧ M. nasalis				
• Pars transversa	Maxilla	Aponeurosis at bridge of nose	B/Z	• Compresses nasal aperture (compressor naris)
• Pars alaris		Ala nasi		• Widens nasal aperture (flares nostril) by drawing ala toward septum nasi
⑨ Levator labii superioris alaeque nasi	Processus frontalis maxillae	Cartilago alaris major and orbital muscles (musculus levator labii superioris and orbicularis oris)	B/Z	Elevates upper lip, increases the curvature of the nasolabial furrow, dilates nostril

* Innervation: The musculi faciei are innervated by six branches of the nervus facialis (CN VII). The posterior muscles are innervated by the nervus auricularis posterior (PA), which arises before the nervus facialis enters the glandula parotidea (see p. 131). The anterior muscles are innervated by five branches off the plexus intraparotideus of the nervus facialis: rami temporalis (T), zygomaticus (Z), buccalis (B), marginalis mandibularis (M), and cervicalis (C).

Musculi Faciei: Mouth

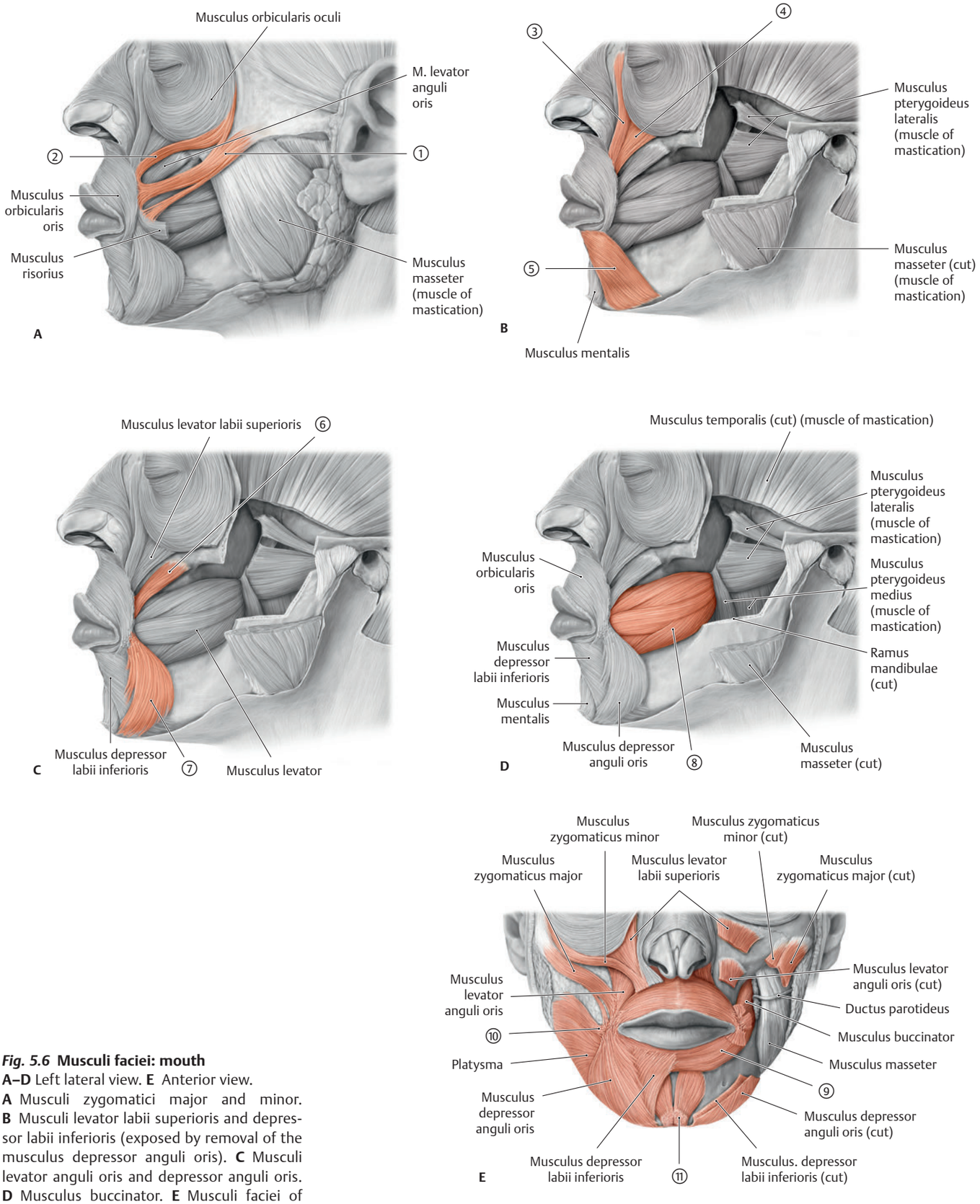


Fig. 5.6 **Musculi faciei: mouth**
A–D Left lateral view. **E** Anterior view.
A Musculi zygomatici major and minor. **B** Musculi levator labii superioris and depressor labii inferioris (exposed by removal of the musculus depressor anguli oris). **C** Musculi levator anguli oris and depressor anguli oris. **D** Musculus buccinator. **E** Musculi faciei of the mouth.

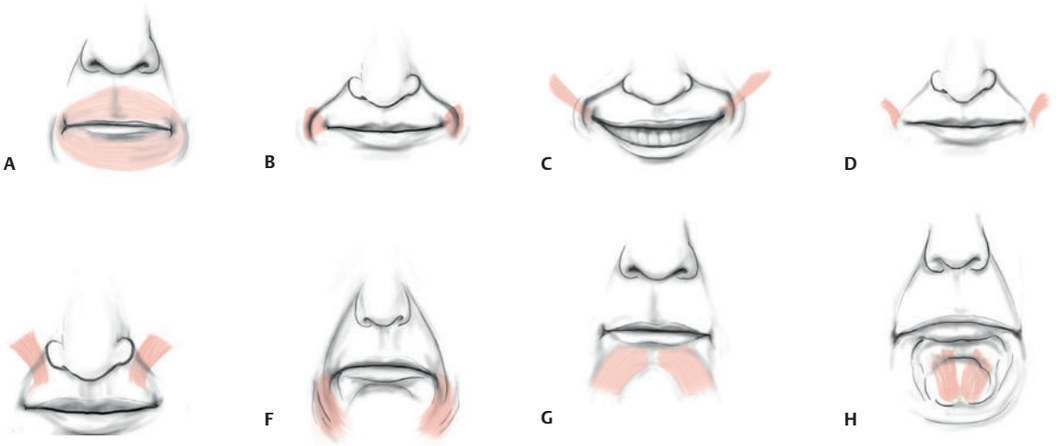


Fig. 5.7 **Changes of facial expression: mouth**
Anterior view.
A Musculus orbicularis oris. **B** Musculus buccinator. **C** Musculus zygomaticus major. **D** Musculus risorius. **E** Musculus levator anguli oris. **F** Musculus depressor anguli oris. **G** Musculus depressor labii inferioris. **H** Musculus mentalis.

Table 5.2 **Musculi faciei: mouth**

Muscle	Origin	Insertion	I*	Main action(s)
① Musculus zygomaticus major	Os zygomaticum (facies lateralis, posterior part)	Muscles at the angle of the mouth	Z	Pulls corner of mouth superiorly and laterally
② Musculus zygomaticus minor		Upper lip just medial to corner of the mouth		Pulls upper lip superiorly
③ Musculus levator labii superioris alaeque nasi	Maxilla (processus frontalis)	Upper lip and cartilago alaris nasi	B/Z	Elevates upper lip; flares nostril
④ Musculus levator labii superioris	Maxilla (processus frontalis) and margo infraorbitalis	Skin of upper lip		Elevates upper lip
⑤ Musculus depressor labii inferioris	Mandibula (anterior portion of linea obliqua)	Lower lip at midline; blends with muscle from opposite side	M	Pulls lower lip inferiorly and laterally, also contributes to eversion (pouting)
⑥ Musculus levator anguli oris	Maxilla (fossa canina, below foramen infraorbitale)	Muscles at the angulus oris	B/Z	Raises angulus oris; helps form nasolabial furrow
⑦ M. depressor anguli oris	Mandibula (linea obliqua below dentes caninus, premolaris, and molaris primus)	Skin at corner of mouth; blends with orbicularis oris	B/M	Pulls angulus oris inferiorly and laterally
⑧ Musculus buccinator	Processus alveolares maxillae and mandibulae (by dentes molares); raphe pterygomandibularis	Lips, orbicularis oris, submucosa of lips and cheek	B	• Suckling in nursing infant • Presses cheek against molar teeth, working with tongue to keep food between occlusal surfaces and out of vestibulum oris; expels air from cavitas oris/resists distention when blowing *Unilateral:* draws mouth to one side
⑨ Musculus orbicularis oris	Deep surface of skin Superiorly: Maxilla (median plane) Inferiorly: Mandibula	Mucous membrane of lips	B/M	Acts as oral sphincter • Compresses and protrudes lip (e.g., whistling, sucking, kissing) • Resists distention (when blowing)
⑩ Musculus risorius	Fascia and superficial muscles over musculus masseter	Skin of corner of mouth	B	Retracts corner of mouth as in smiling, laughing, grimacing
⑪ Musculus mentalis	Frenulum labii inferioris	Skin of chin	M	Elevates and protrudes lower lip (drinking)
Platysma	Skin over lower neck and upper lateral thorax	Mandibula (inferior border); skin over lower face; angulus oris	C	Depresses and wrinkles skin of lower face and mouth; tenses skin of neck; aids in forced depression of the mandibula

* Innervation: The musculi faciei are innervated by six branches of the nervus facialis (CN VII). The posterior muscles are innervated by the nervus auricularis posterior (PA), which arises before the nervus facialis enters the glandula parotidea. The anterior muscles are innervated by five branches off the plexus intraparotideus of the nervus facialis: rami temporalis (T), zygomaticus (Z), buccalis (B), marginalis mandibularis (M), and cervicalis (C).

Neurovascular Topography of the Anterior Face & Scalp: Superficial Layer

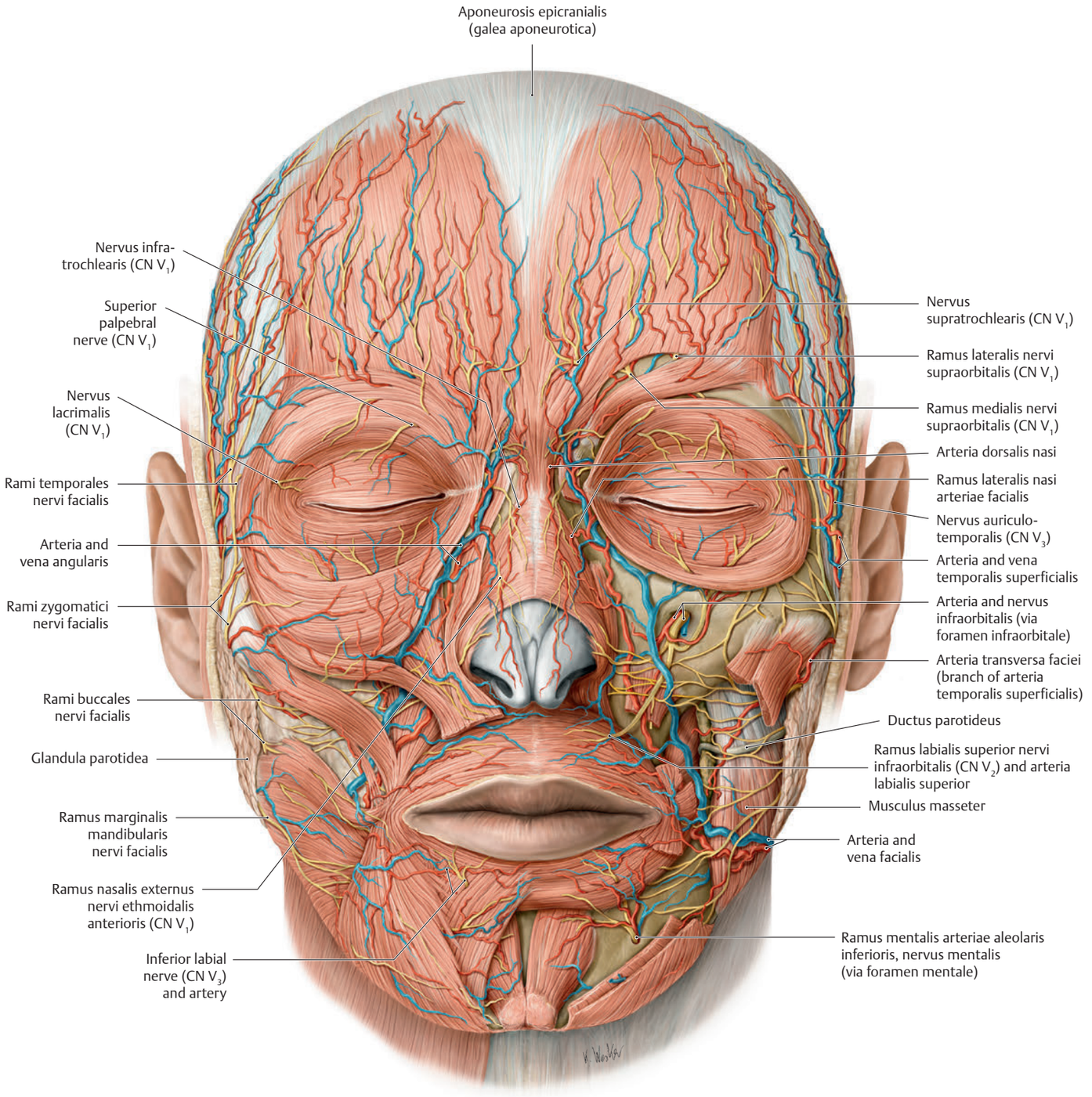


Fig. 5.8 **Neurovasculature of the superficial layer of the anterior face**

Anterior view. *Removed:* Skin and fatty tissue. The musculi faciei have been partially removed on the left side to display underlying musculature and neurovascular structures. The musculi faciei receive motor innervation from the nervus facialis (CN VII), which emerges laterally from the glandula parotidea. The muscles of mastication receive motor innervation from the nervus mandibularis of the nervus trigeminus (CN V_3). The face receives sensory innervation primarily from the terminal branches of the three divisions of the nervus trigeminus (CN V), but also from the nervus auricularis magnus, which arises from the plexus cervicalis (see pp. 316 and 317). The face receives blood supply primarily from branches of the arteria carotis externa, though these do anastomose on the face with facial branches of the arteria carotis interna (see **Fig. 3.12**).

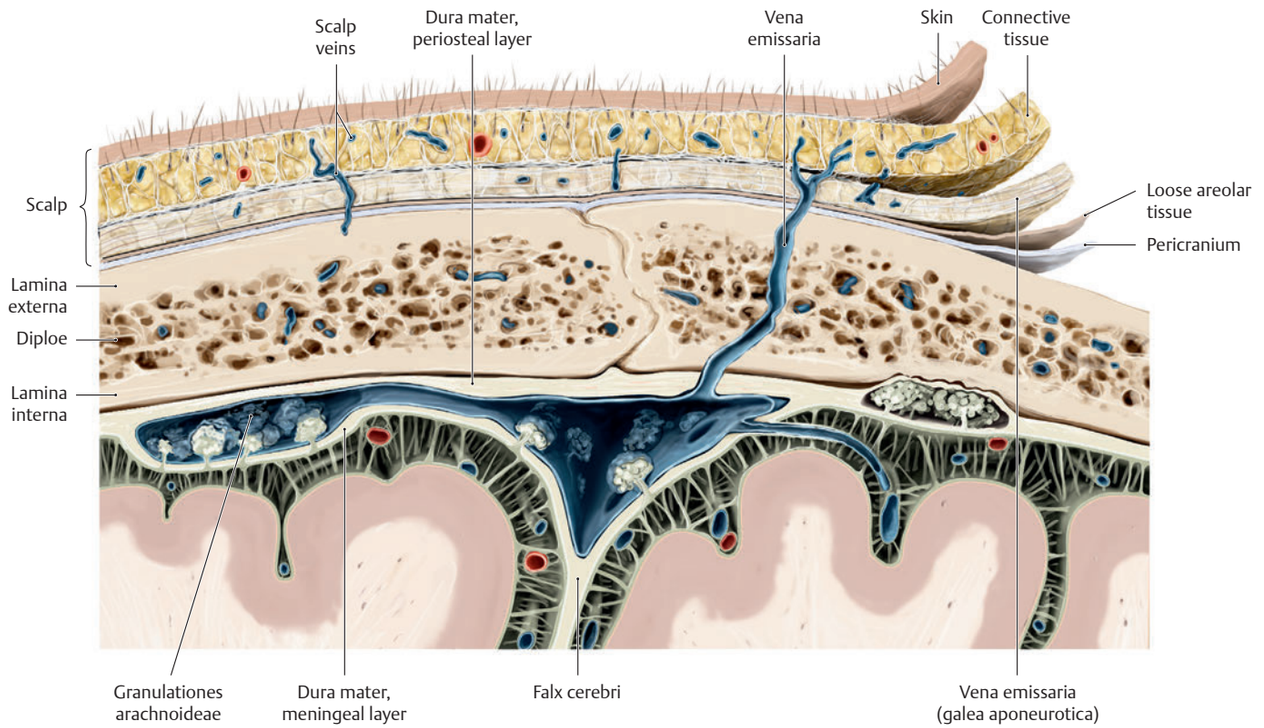


Fig. 5.9 **Scalp**
The scalp consists of five layers. From superficial to deep, these are **S**kin, **C**onnective tissue, epicranical **A**poneurosis (galea aponeurotica), **L**oose areolar tissue, and **P**ericranium.
Scalp infections are able to spread easily through the loose connective tissue layer. They may spread intracranially to the sinus durae matris through venae emissariae, causing meningitis, or to the eyelids or nose because the frontalis muscle inserts into the skin and subcutaneous tissue but does not attach to bone. Infections that spread to the eyelid cause rapid swelling because the skin of the eyelid is very thin and it covers a loose connective tissue layer. Scalp infections are unable to spread into the neck because the ventri occipitales of the musculi occipitofrontales attach to the os occipitale and the processus mastoideus of the os temporale. Likewise they are prevented from spreading laterally beyond the arci zygomatici because the aponeurosis epicranialis is continuous with the fascia temporalis, which attaches to the arci zygomatici.
Scalp lacerations bleed profusely because the arteries entering the periphery of the scalp bleed from both ends owing to extensive anastomoses. Furthermore, the arteries do not contract to arrest bleeding because they are held open by the dense connective tissue layer of the scalp.The musculus occipitofrontalis may go into spasm following scalp laceration causing the wound to gape. Scalp lacerations should be sutured or otherwise controlled as soon as possible after injury to prevent serious, sometimes fatal, loss of blood.

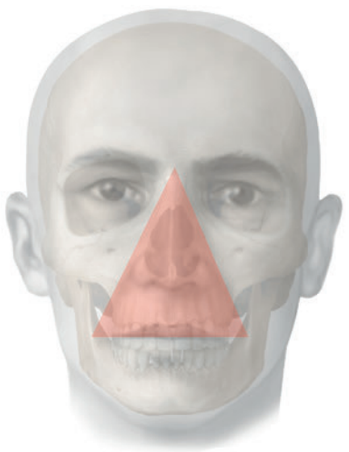


Fig. 5.10 **Venous “danger zone” in the face**
The superficial veins of the face have extensive connections with the deep veins of the head (e.g., the plexus pterygoideus) and sinus durae matris (e.g., the sinus cavernosus) (see p. 66). Veins in the triangular danger zone are, in general, valveless. There is therefore a particularly high risk of bacterial dissemination into the cavitas cranii. For example, bacteria from a boil on the lip may enter the vena facialis and cause meningitis by passing through venous communications with the sinus cavernosus.

Neurovascular Topography of the Lateral Head: Superficial Layer

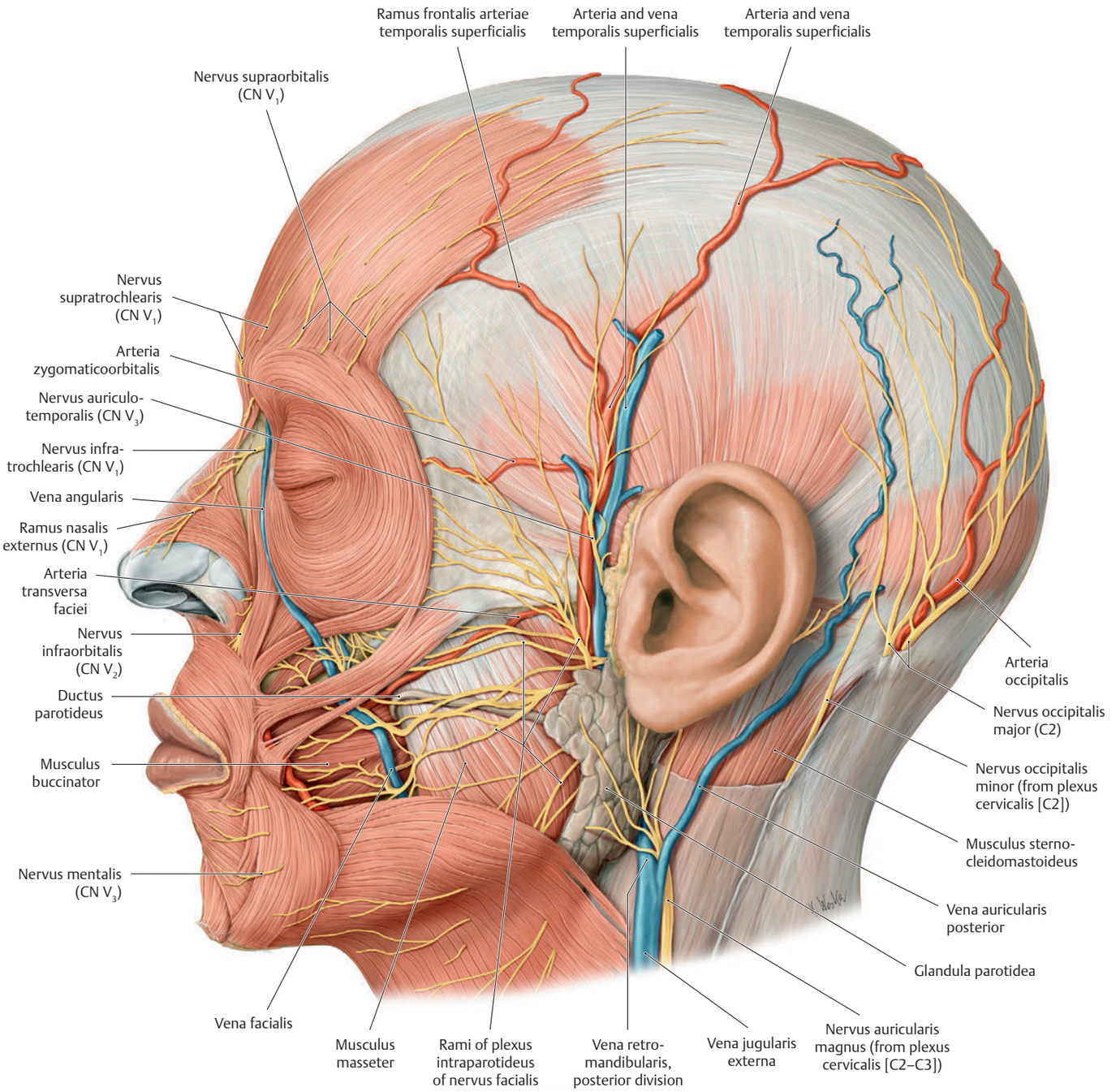


Fig. 5.11 **Neurovasculature of the superficial layer of the lateral head**

Left lateral view. The arteries supplying the lateral head arise from branches of the arteria carotis externa (see **Fig. 5.12**). Blood drains primarily into the venae jugulares interna, externa, and anterior (see p. 62). The musculi faciei receive motor innervation from the nervus facialis (CN VII), which emerges laterally from the glandula parotidea (see p. 133). The muscles of mastication receive motor innervation from the nervus mandibularis division of the nervus trigeminalis (CN V_3, see p. 128). The sensory innervation of the face is shown in **Fig. 5.13**.

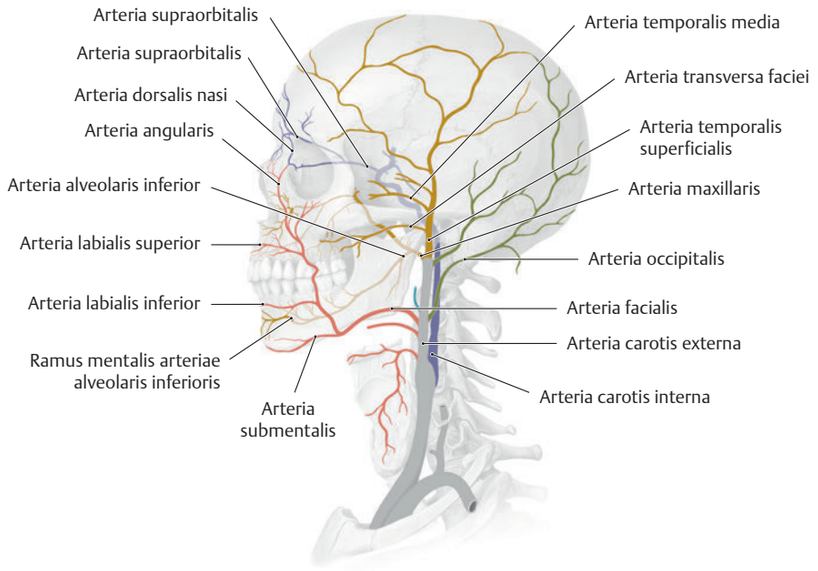


Fig. 5.12 **Superficial arteries of the head**
Left lateral view. The superficial face is supplied primarily by branches of the arteria carotis externa (e.g., arteriae facialis, temporalis superficialis, and maxillaris). However, there is a limited contribution from branches derived from the arteria carotis interna in the region of the orbital rim.
Note: The arteria carotis interna is colored purple and the anterior, medial, posterior, and terminal branches of the arteria carotis externa are colored red, blue, green, and yellow, respectively.

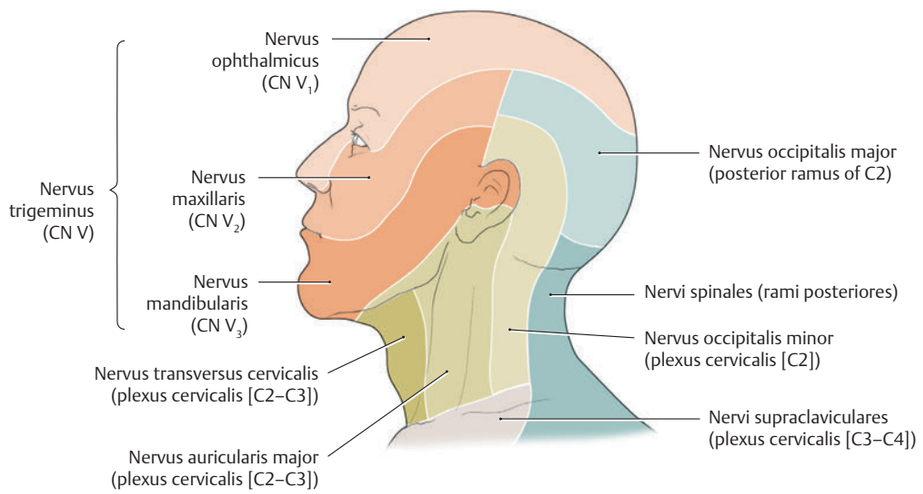


Fig. 5.13 **Sensory innervation of the lateral head and neck**
Left lateral view. The head receives sensory innervation primarily from the nervus trigeminus (orange), the plexus cervicalis (green and gray), and the ramik posteriores of the nervi spinales (blue). Sensory supply to the face is primarily from the terminal branches of the three nervus trigeminus divisions. The occiput and nuchal region are supplied primarily by rami posteriores of the nervi spinales. The rami anteriores of the first four nervi spinales combine to form the plexus cervicalis. The plexus cervicalis gives off four cutaneous branches that supply the lateral head and neck (nerves listed with their associated spinal nerve fibers): nervus auricularis minor (C2, occasionally C3), nervus auricularis major (C2–C3), nervus transversus cervicalis (C2–C3), and nervi supraclaviculares (C3–C4) (see **Fig. 12.3**).

Neurovascular Topography of the Lateral Head: Intermediate & Deep Layers

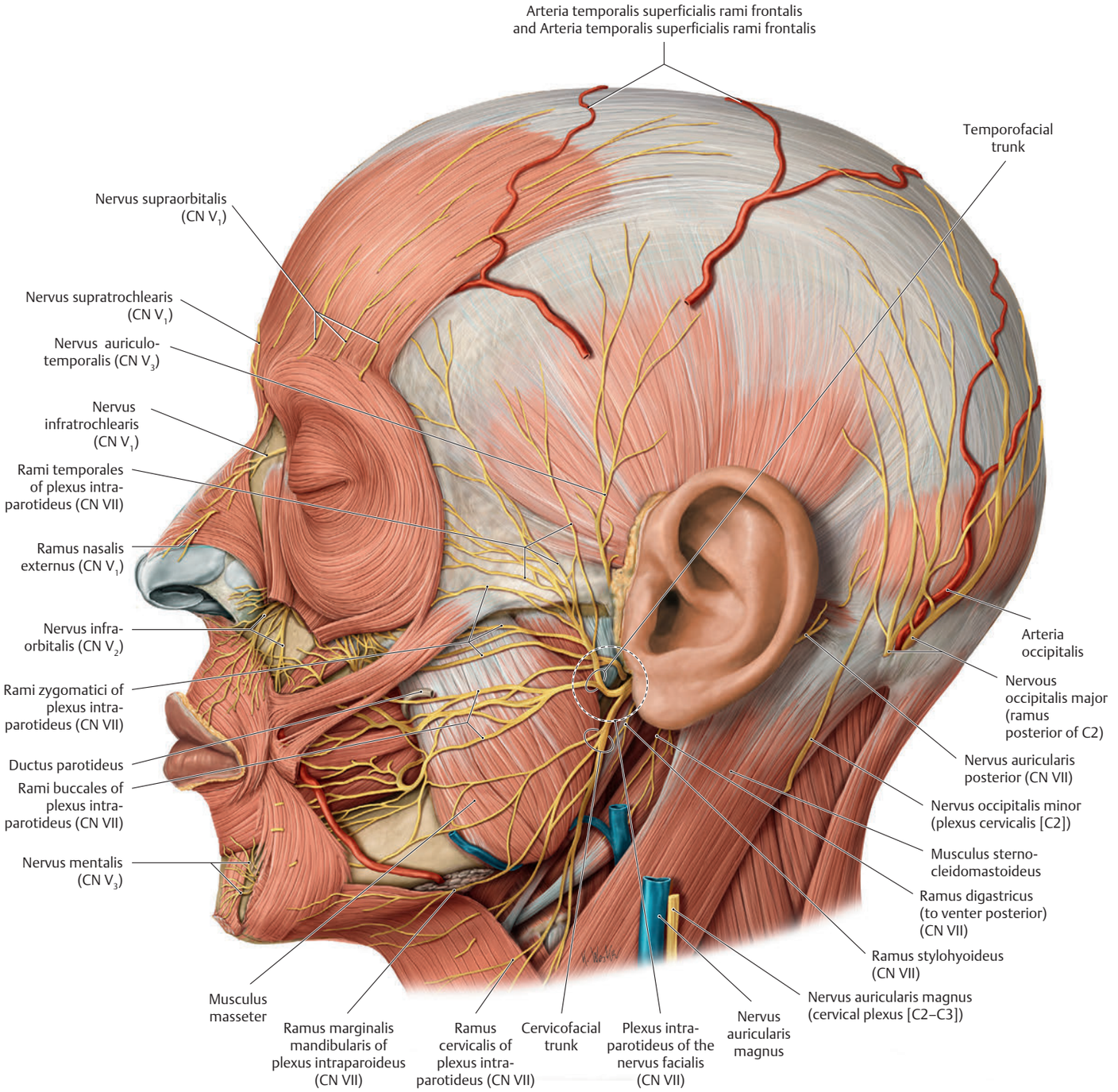


Fig. 5.14 **Nerves of the intermediate layer of the lateral head**
Left lateral view. The glandula parotidea has been removed to demonstrate the structure of the plexus intraparotideus of the nervus facialis (see **Fig. 4.88**). The occiput receives sensory innervation from the greater occipital nerve, which arises from the ramus posterior of C2, and the nervus occipitalis minor, which arises from the plexus cervicalis (rami anteriores of C2).

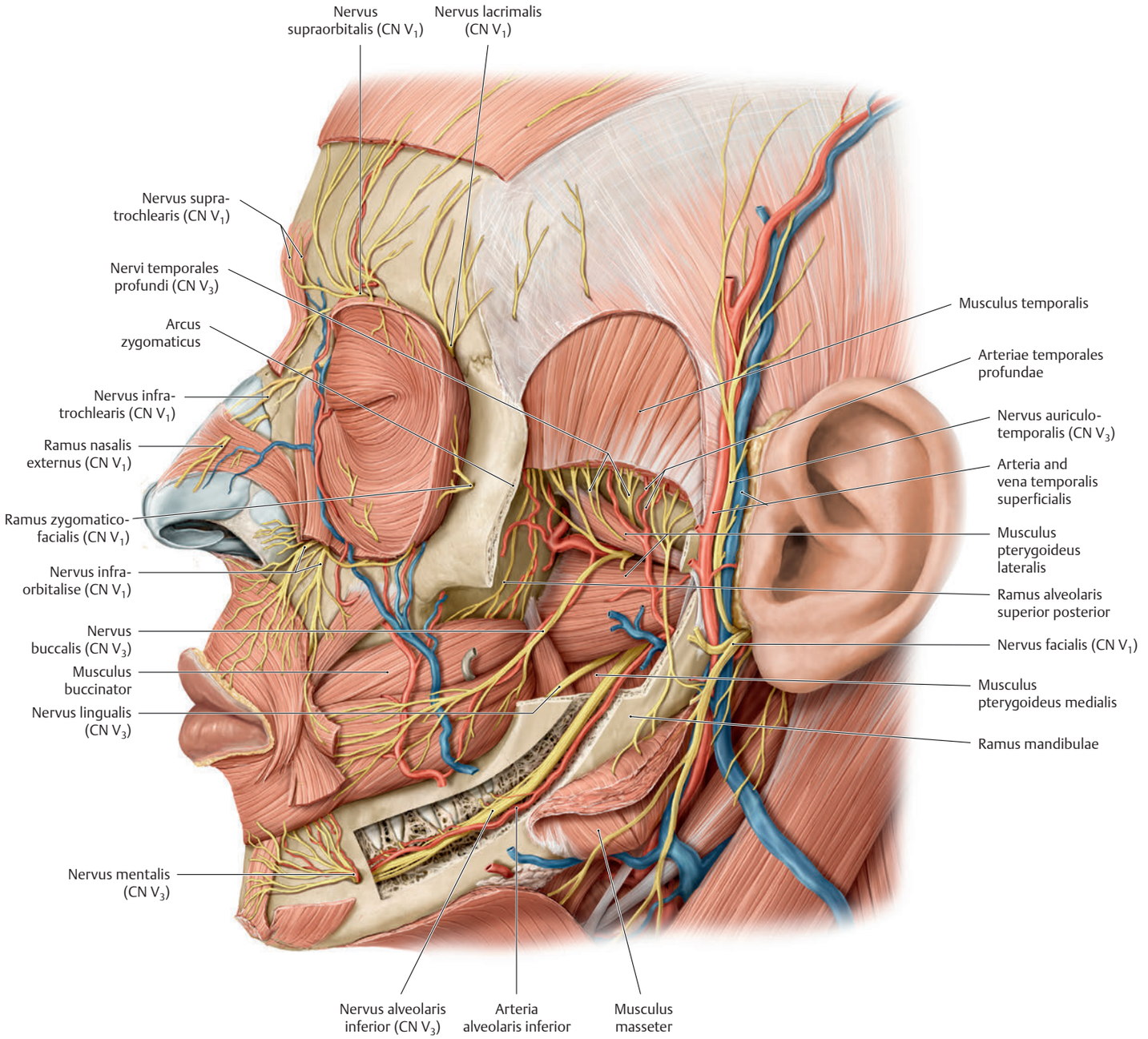


Fig. 5.15 **Neurovasculature of the lateral face**
Left lateral view. The musculus masseter and arcus zygomaticus have been windowed to reveal the deep structures. Also, the ramus and corpus of the mandibula have been opened to demonstrate neurovascular structures that traverse it.

Fossae Temporalis & Infratemporalis: Contents

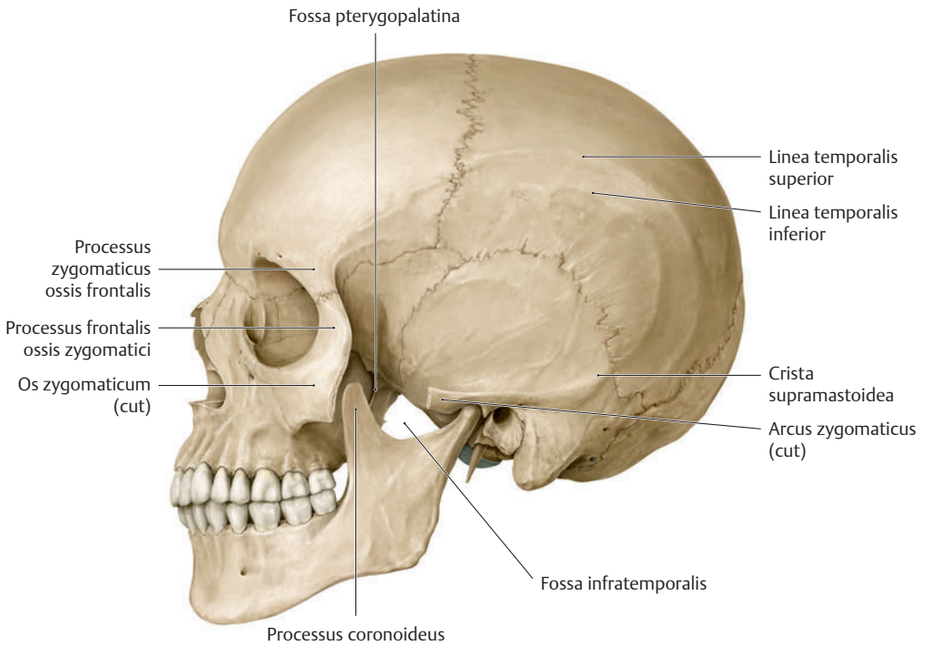


Fig. 6.1 **Fossa temporalis**
Left lateral view. The fossa temporalis is located on the lateral aspect of the skull. Its boundaries are listed in **Table 6.1**. The fossa temporalis communicates with the fossa infratemporalis inferiorly (medial to the arcus zygomaticus). The fossa pterygopalatina can also be seen here medial to the fossa infratemporalis due to the removal of the arcus zygomaticus and some of the os zygomaticum.

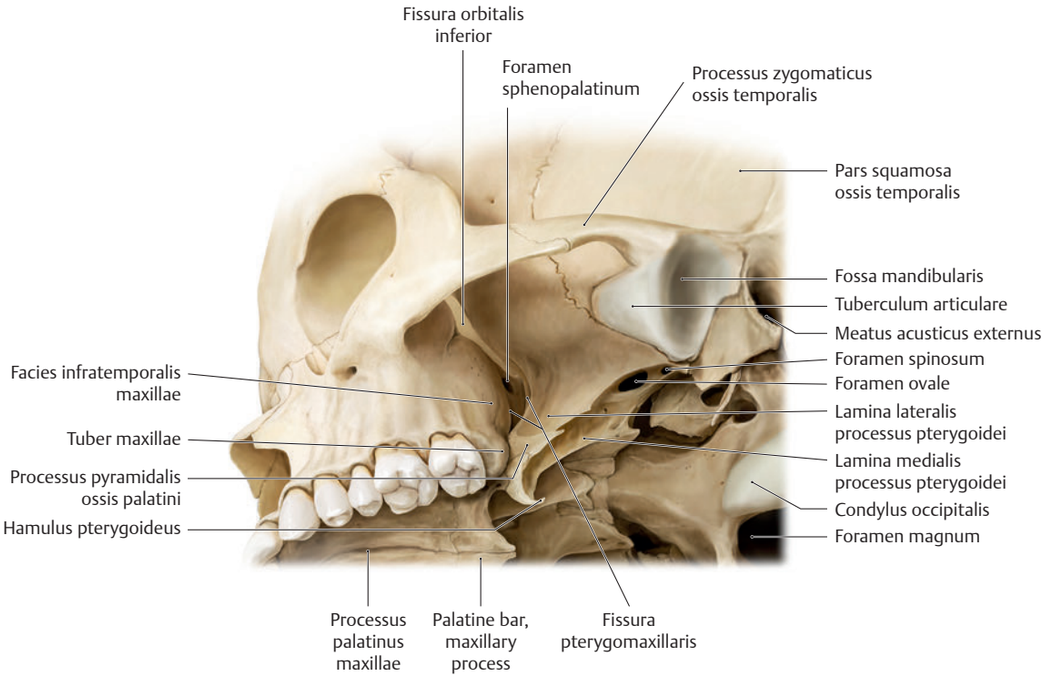


Fig. 6.2 **Fossa infratemporalis**
Oblique external view of the base of the skull. The fossa infratemporalis bony boundaries are listed in **Table 6.3**. The fossa infratemporalis communicates *medially* with the fossa pterygopalatina via the fissura pterygomaxillaris; *anteriorly* with the orbita via the fissura orbitalis inferior; *superiorly* with the fossa cranii media via foramen ovale and foramen spinosum, and with the fossa temporalis passing medial to the arcus zygomaticus.

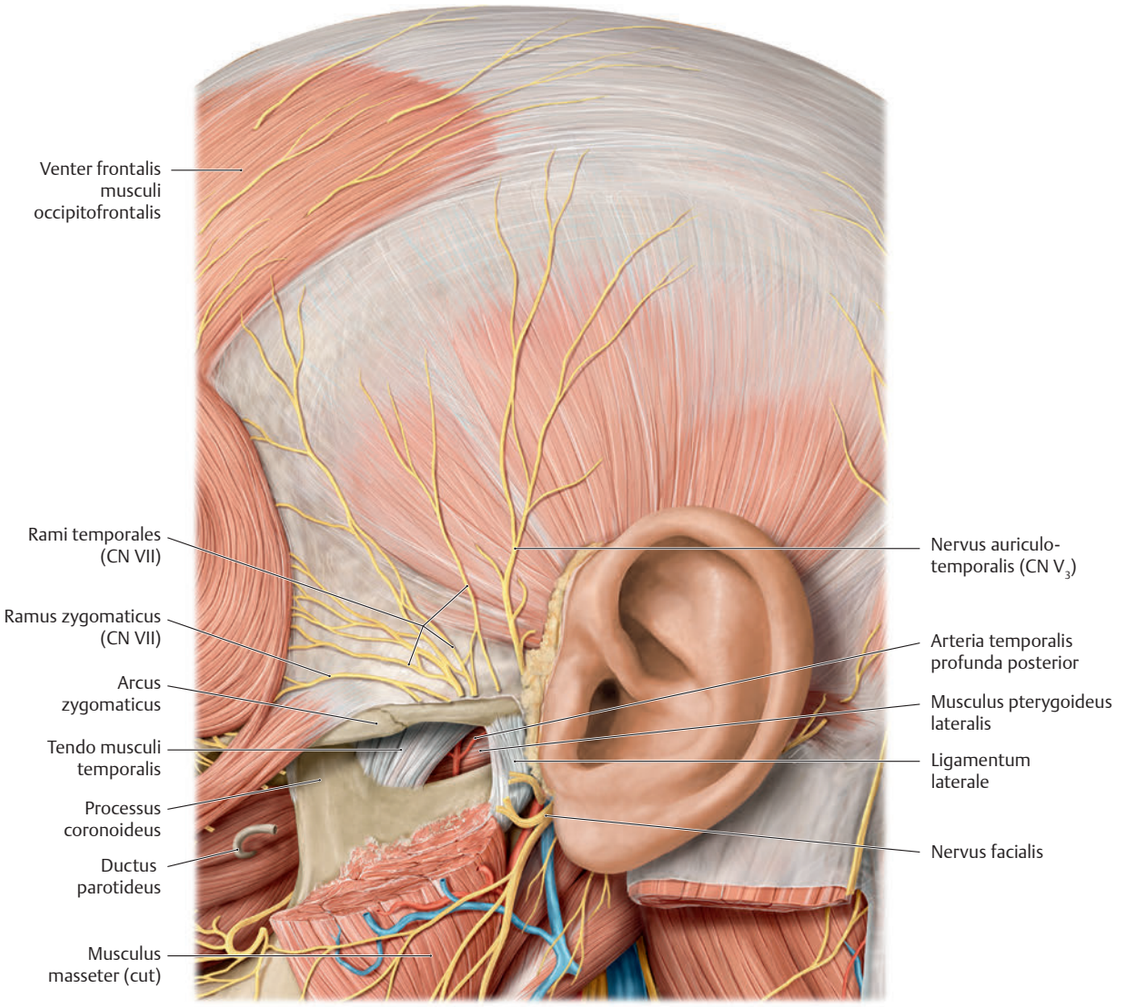


Fig. 6.3 **Neurovascular topography of the fossa temporalis**
Left lateral view. *Cut:* Musculus masseter. *Revealed:* Fossa temporalis and articulatio temporomandibularis. The muscles and neurovasculature of the fossa temporalis are listed in **Table 6.2**.

Table 6.1 **Borders of the fossa temporalis**

Superior	Lineae temporales superior and inferior
Inferior	Arcus zygomaticus (laterally); crista temporalis (alae majoris ossis sphenoidalis) (medially)
Anterior	Processus frontalis ossis zygomatici; processus zygomaticus ossis frontalis
Posterior	Crista supramastoidea
Medial	Ossa sphenoidale, temporale, parietale, and frontale
Lateral	Fascia temporalis

Table 6.2 **Muscles and neurovasculature of the fossa temporalis**

Muscle	Vasculature	Nerves
Temporalis	Arteria and vena temporalis superficialis	Nervus auriculotemporalis (CN V_3)
	Arteriae and venae temporales profundae	Nervi temporales profundi (CN V_3)
		Rami temporales (CN VII)

Fossa Infratemporalis: Contents

The fossa infratemporalis is located lateral to the lamina lateralis processus pterygoidei of the os sphenoidale, medial to the ramus mandibulae, posterior to the maxilla, anterior to the processus styloideus (and the vagina carotica and its contents), and inferior to the ala major of the os sphenoidale and a small part of the os temporale. It is continuous with the fossa pterygopalatina (through the fissura pterygomaxillaris). The arteria maxillaris gives rise to its rami mandibularis (bony, first part) and pterygoideus (muscular, second part) in the fossa infratemporalis. The nervus mandibularis division of the nervus trigeminus (CN V_3) divides into its terminal branches in the fossa infratemporalis.

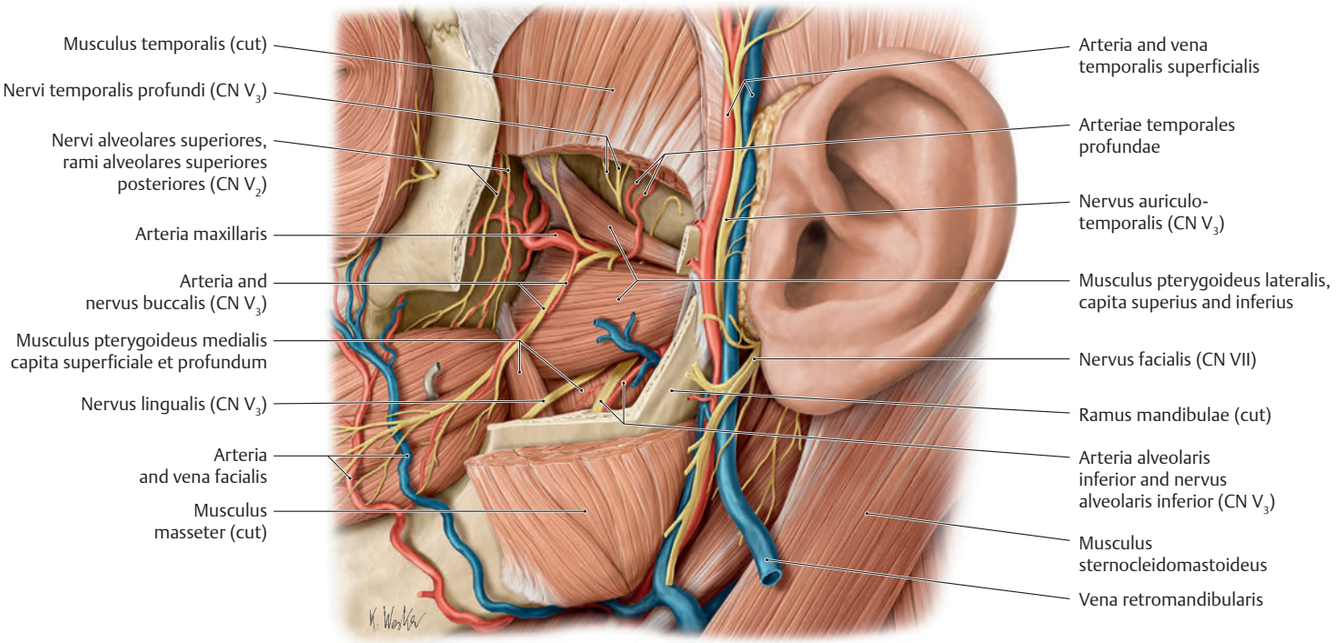


Fig. 6.4 **Fossa infratemporalis, superficial dissection**
Left lateral view. *Removed:* Musculus masseter, anterior portion of the ramus mandibulae, and arcus zygomaticus. The plexus pterygoideus normally is embedded between the musculi pterygoidei medialis and lateralis. It drains to the vena maxillaris, a tributary of the vena retromandibularis. The Arteria alveolaris inferior and nervus alveolaris inferior can be seen entering the canalis mandibulae (the accompanying vein has been removed).

Table 6.3 **Borders of the fossa infratemporalis**

Superior*	Inferior surface of the ala major of the sphenoid bone Pars squamosa ossis temporalis (small contribution)
Inferior	Demarked by an imaginary line that is an inward extension of the mandibular plane
Anterior	Facies infratemporalis maxillae
Posterior	Processus styloideus and contents of vagina caroticus
Medial	Lateral surface of the lamina lateralis processus pterygoidei ossis sphenoidalis and processus pyramidalis ossis palatini
Lateral	Medial surface of the ramus mandibulae

* The crista infratemporalis (alae majoris ossis sphenoidalis) separates the roof from the fossa temporalis above.

Table 6.4 **Muscles and vessels of the fossa infratemporalis**

Muscles	Arteries	Veins
Musculi pterygoidei lateralis and medialis	Arteria maxillaris • Mandibular branches • Pterygoid branches	Plexus pterygoideus and its tributaries
Tendo temporalis		Venae maxillares
		Vena profunda faciei (deep portion)
		Venae emissariae

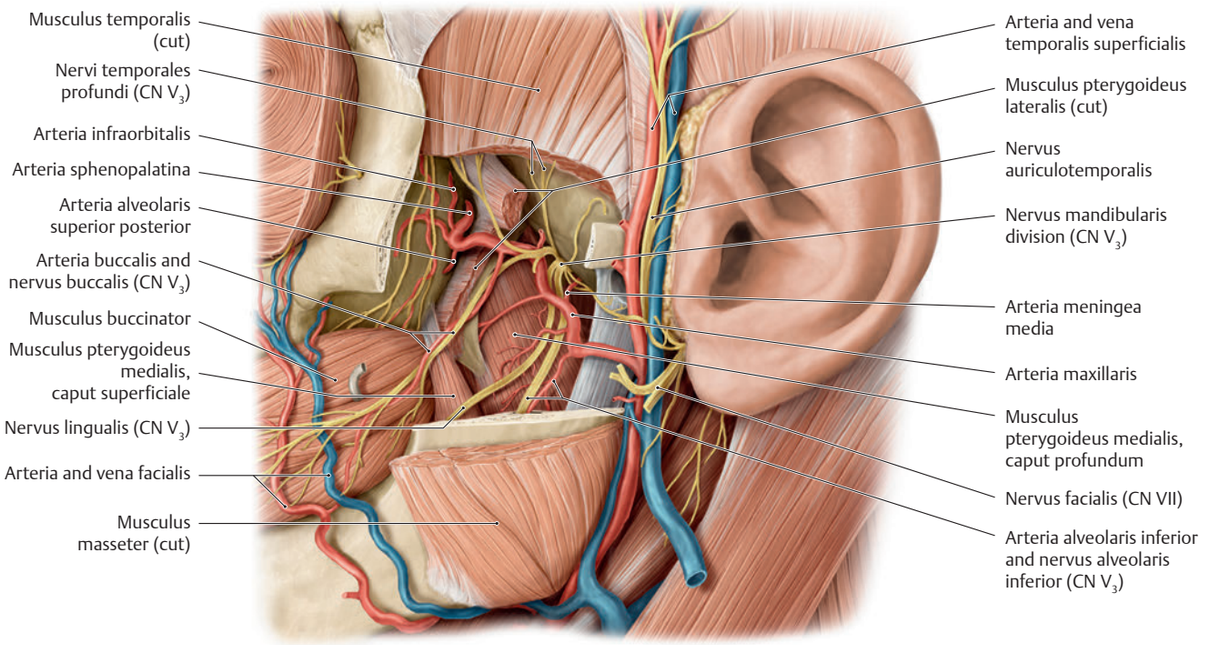


Fig. 6.5 **Fossa infratemporalis, deep dissection**
Left lateral view. *Removed:* Both heads of the musculus pterygoideus lateralis. The branches of the arteria maxillaris and nervus mandibularis division of the nervus trigeminus (CN V_3) can be identified. *Note:* By careful observation, it is possible to define the site where the nervus auriculotemporalis (branch of the nervus mandibularis) splits around the arteria meningea media before the artery enters the fossa cranii media through the foramen spinosum. Branches of the third part of the arteria maxillaris can be observed in the fossa pterygopalatina, which is medial to the fossa infratemporalis.

Table 6.5 **Nerves in the fossa infratemporalis**

CN V_3	Trunk of CN V_3 and direct branches:
	• Recurrent ramus meningeus (nervus spinosus)
	• Nervus pterygoideus medialis
	  • Nervus musculi tensoris veli palatini
	  • Nervus tensoris tympani
		Anterior division:
		• Nervus massetericus
		• Nervi temporales profundi
		• Nervus buccalis
		• Nervus pterygoideus lateralis
			Posterior division:
			• Nervus auriculotemporalis
			• Nervus lingualis
			• Nervus alveolaris inferior
			  • Nervus mylohyoideus

CN V_2	Ramus alveolaris superior posterior		
Other	Ganglion oticum	Nervus petrosus minor (CN IX)	Chorda tympani (CN VII)
The anterior aspect of the fossa infratemporalis is the site of needle placement for a posterior superior alveolar nerve block (p. 477).			

Musculi Masticatorii: Overview

The musculi masticatorii are located at various depths in the parotid and infratemporal regions of the face. They attach to the mandibula and receive their motor innervation from the nervus mandibularis division of the nervus trigeminus (CN V_3).

Table 6.6 **Musculi masseter and temporalis**

Muscle		Origin	Insertion	Innervation*	Action
Musculus masseter	① Caput superficiale	Os zygomaticum (processus maxillaris) and arcus zygomaticus (lateral aspect of anterior ⅔)	Angulus and ramus mandibulae (inferior lateral surface)	Nervus masseteri-cus (anterior division of CN V_3)	Elevates mandibula; also assists in protraction, retraction, and side-to-side motion
	Caput mediale	Arcus zygomaticus (medial aspect of anterior ⅔)	Ramus mandibulae (central part of occlusal surface)		
	② Caput profundum	Arcus zygomaticus (deep surface of posterior ⅓)	Ramus mandibulae (superior lateral surface) and inferior processus coronoideus		
Musculus temporalis	③ Caput superficiale	Fascia temporalis	Processus coronoideus mandibulae (apex, medial surface, and anterior surface of ramus mandibulae)	Nervi temporales profundi (anterior division of CN V_3)	*Vertical (anterior) fibers:* Elevate mandibula *Horizontal (posterior) fibers:* Retract (retrude) mandibula *Unilateral:* Lateral movement of mandibula (chewing)
	④ Caput profundum	Fossa temporalis (linea temporalis inferior)			

* The muscles of mastication are innervated by motor branches of the nervus mandibularis (CN V_3), the 3rd division of the nervus trigeminus (CN V).

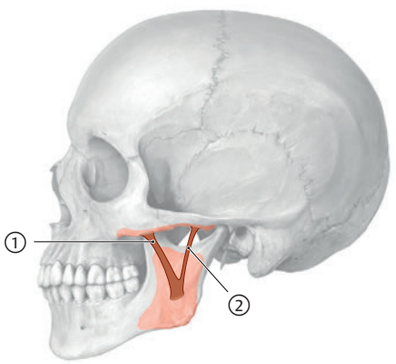


Fig. 6.6 **Musculus masseter**

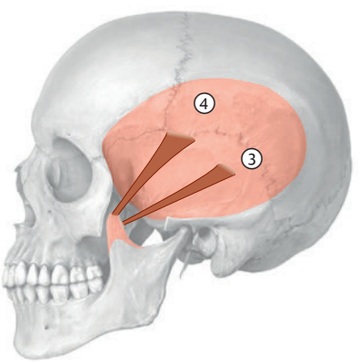


Fig. 6.7 **Musculus temporalis**

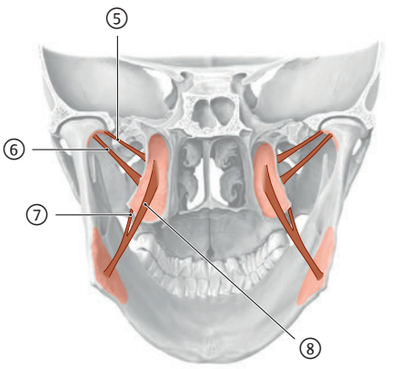


Fig. 6.8 **Musculi pterygoidei**

Table 6.7 **Lateral and medial pterygoid muscles**

Muscle		Origin	Insertion	Innervation	Action
Musculus pterygoi-deus lateralis	⑤ Caput superius	Ala major ossis sphenoidalis (crista infratemporalis)	Mandibula (fovea pterygoidea) and articulatio temporomandibularis (discus articularis)	Nervus pterygoideus lateralis (anterior division of CN V_3)	*Bilateral:* Protrudes mandibula (pulls discus articularis forward) and opens mouth. *Unilateral:* Alternating actions, along with ipsilateral musculus pterygoideus medialis, result in side-to-side movements necessary for grinding.
	⑥ Caput inferius	Lamina lateralis processus pterygoidei (lateral surface)	Mandibula (fovea pterygoidea and processus condylaris)		
Musculus pterygoi-deus medialis	⑦ Caput superficiale (external)	Maxilla (tuber maxillae) and os palatinum (processus pyramidalis)	Tuberositas pterygoidea on medial surface of the angulus mandibulae	Nervus pterygoideus medialis (anterior division of CN V_3)	*Bilateral:* Elevation of mandibula; also acts with musculus pterygoideus lateralis to assist in protrusion of mandibula. *Unilateral:* Acts with ipsilateral musculus pterygoideus lateralis to protrude mandibula and produce medial movement toward the opposite side. Alternating actions between right and left sides results in side-to-side chewing movements.
	⑧ Caput profundum (internal)	Medial surface of lamina lateralis processus pterygoidei and fossa pterygoidea			

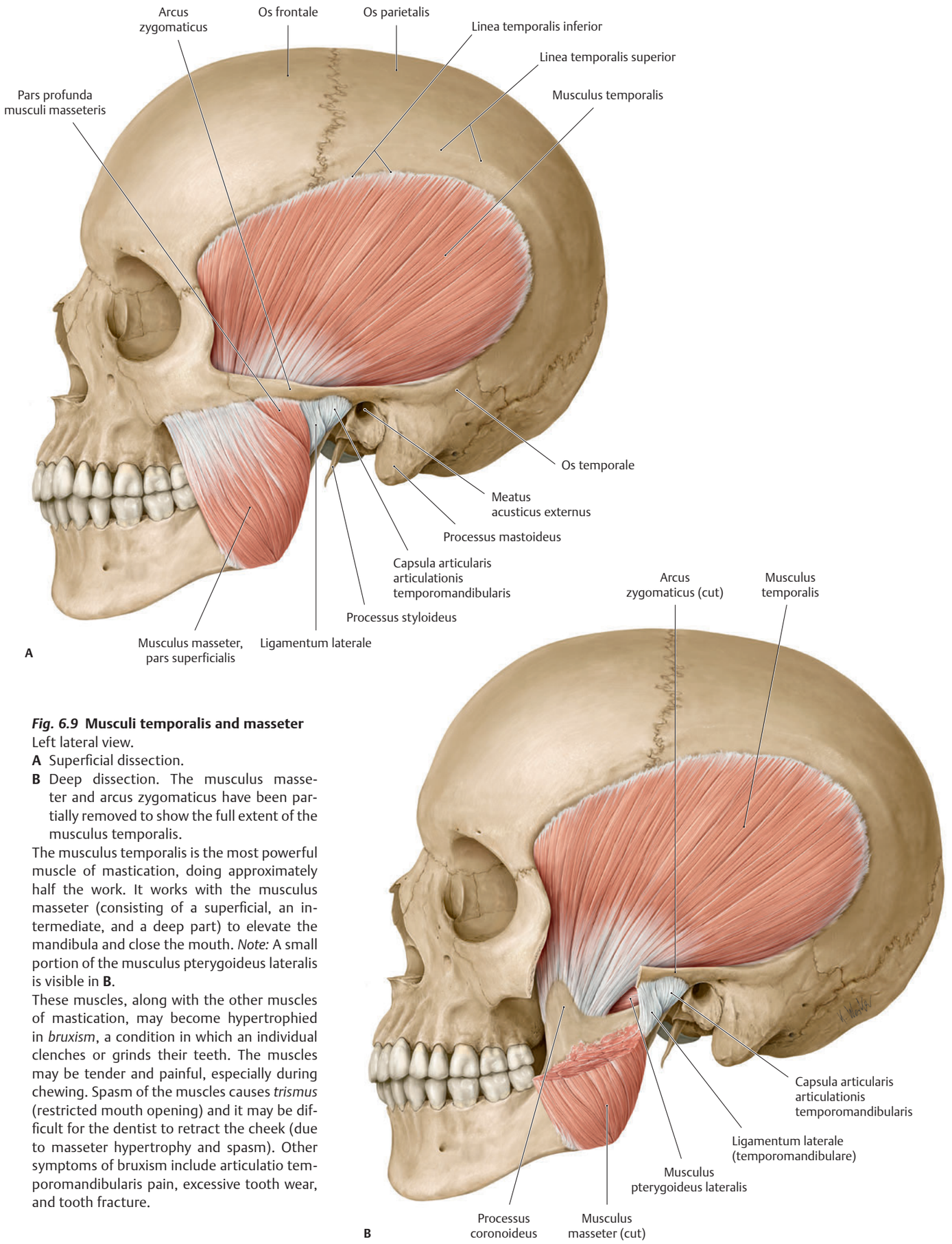


Fig. 6.9 **Musculi temporalis and masseter**
Left lateral view.

A Superficial dissection.

B Deep dissection. The musculus masseter and arcus zygomaticus have been partially removed to show the full extent of the musculus temporalis.

The musculus temporalis is the most powerful muscle of mastication, doing approximately half the work. It works with the musculus masseter (consisting of a superficial, an intermediate, and a deep part) to elevate the mandibula and close the mouth. *Note:* A small portion of the musculus pterygoideus lateralis is visible in **B**.

These muscles, along with the other muscles of mastication, may become hypertrophied in *bruxism*, a condition in which an individual clenches or grinds their teeth. The muscles may be tender and painful, especially during chewing. Spasm of the muscles causes *trismus* (restricted mouth opening) and it may be difficult for the dentist to retract the cheek (due to masseter hypertrophy and spasm). Other symptoms of bruxism include articulatio temporomandibularis pain, excessive tooth wear, and tooth fracture.

Musculi Masticatorii: Deep Muscles

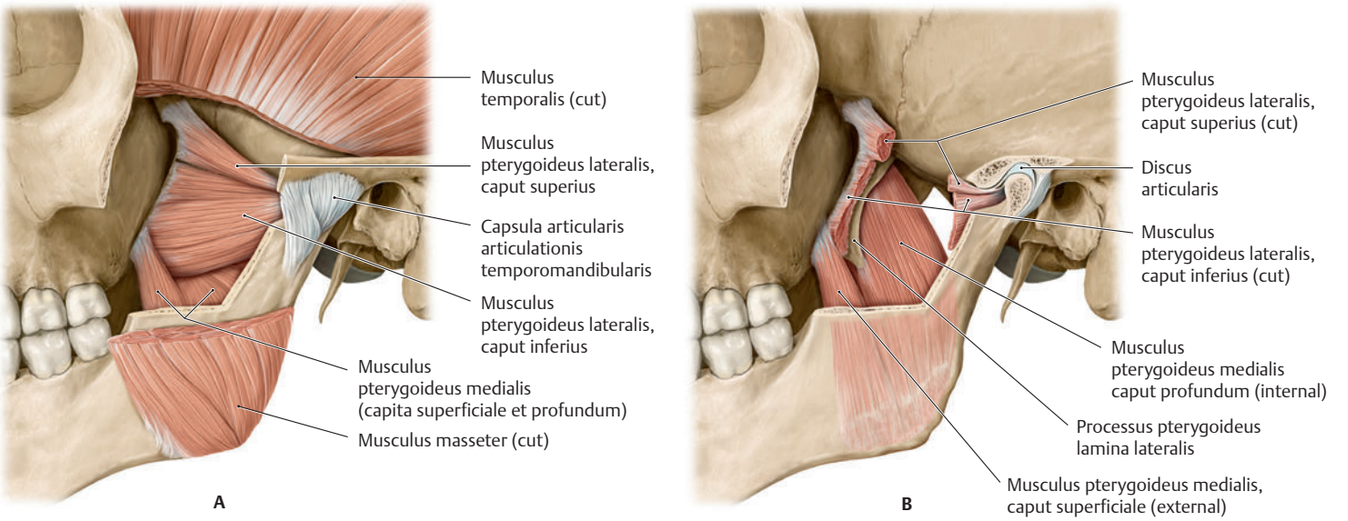


Fig. 6.10 **Musculi pterygoidei lateralis and medialis**
Left lateral views.

A The processus coronoideus mandibulae has been removed here along with the lower part of the musculus temporalis so that both musculi pterygoidei are observed (see **Fig. 6.9B**).

B Here the musculus temporalis has been completely removed, and the caput inferius of the musculus pterygoideus lateralis has been windowed. The musculus pterygoideus *lateralis* initiates depression of the mandibula which is then continued by the musculi suprahyoidei and infrahyoidei and gravity. With the articulatio temporomandibularis opened, we can see that fibers from the caput superius of the musculus pterygoideus lateralis blend with the discus articularis. The musculus pterygoideus lateralis functions as the guide muscle of the articulatio temporomandibularis. The musculus pterygoideus *medialis* runs almost perpendicular to the musculus pterygoideus lateralis and contributes to the formation of a muscular sling that partially encompasses the mandibula (see **Fig. 6.11**). Note how the caput inferius of the musculus pterygoideus lateralis originates between the two heads of the musculus pterygoideus medialis.

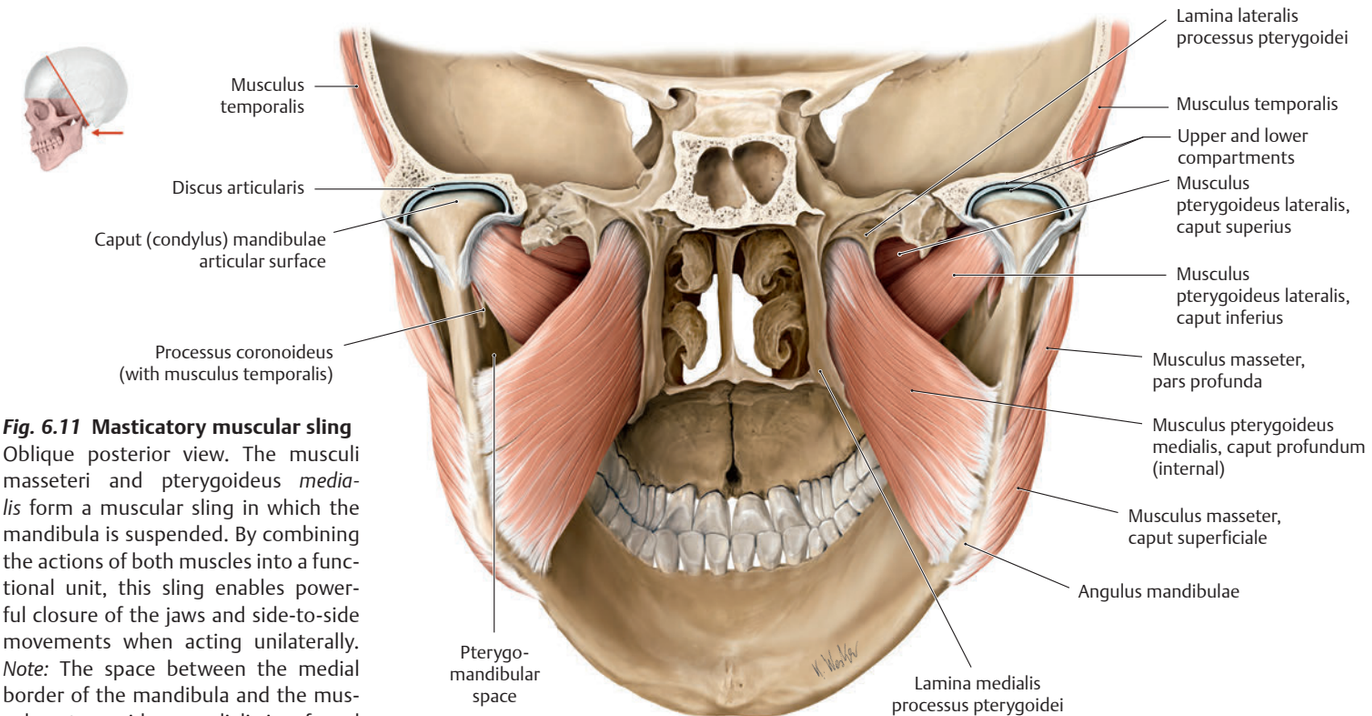


Fig. 6.11 **Masticatory muscular sling**
Oblique posterior view. The musculi masseteri and pterygoideus *medialis* form a muscular sling in which the mandibula is suspended. By combining the actions of both muscles into a functional unit, this sling enables powerful closure of the jaws and side-to-side movements when acting unilaterally. *Note:* The space between the medial border of the mandibula and the musculus pterygoideus medialis is referred to as the pterygomandibular space. It is important as it is the target area for administering local anesthesia to the inferior alveolar nerve.

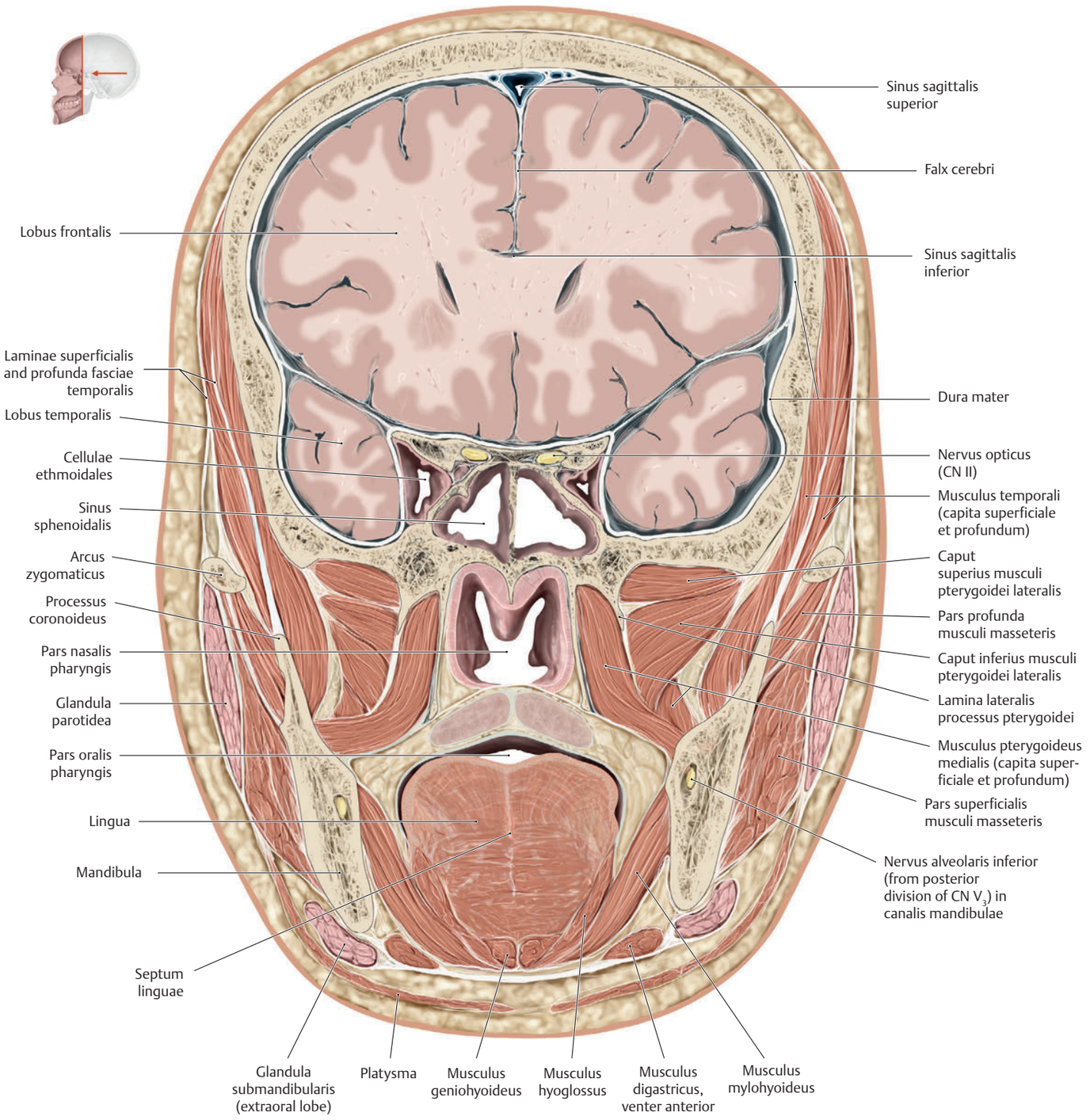


Fig. 6.12 **Musculi masticatorii, coronal section at the level of the sphenoid sinus**

Posterior view. The topography of the muscles of mastication and neighboring structures is particularly well displayed in this section.

The muscles of mastication can be bimanually palpated to assess for hypertrophy or tenderness. To palpate the musculus temporalis, the clinician places his fingers over the temporal region and works his way down the length of this muscle from superior to inferior; to palpate the musculus masseter the patient is asked to put their teeth together without clenching while the clinician palpates over the lateral cheek from superior to inferior; the musculus pterygoideus lateralis is palpated by the clinician placing his index or little finger in the buccal sulcus as far posteriorly as possible and palpating in a posterior, superior, and medial direction (it is a source of some debate whether this actually allows for palpation of the musculus pterygoideus lateralis); the musculus pterygoideus medialis is palpated along the medial border of the corpus mandibulae and angulus mandibulae.

Articulatio Temporomandibularis (TMJ)

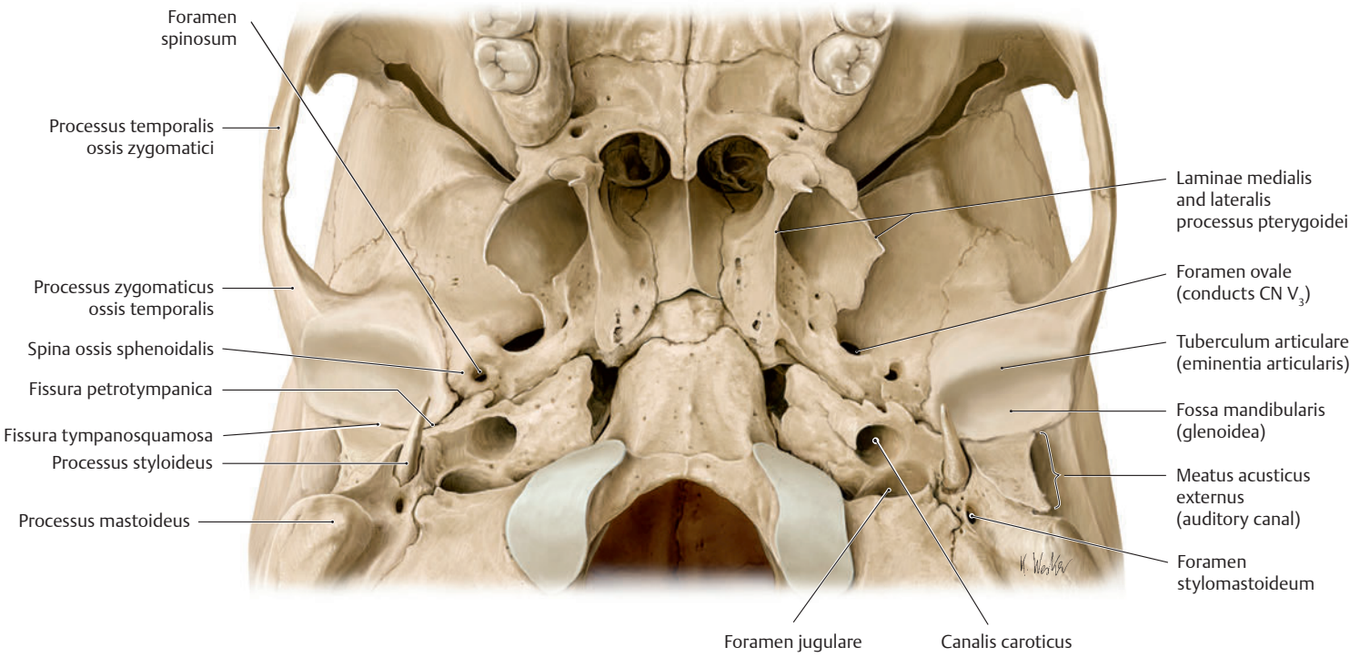


Fig. 6.13 **Fossa mandibularis (glenoidea) articulationis temporomandibularis**

Inferior view. The caput mandibulae articulates with the discus articularis in the fossa mandibularis (glenoidea) of the os temporale. The fossa mandibularis is a depression in the pars squamosa of the os temporale. The tuberculum articulare is located on the anterior side of the fossa mandibularis. The caput mandibulae is markedly smaller than the fossa mandibularis, allowing it to have an adequate range of movement. Unlike other articular surfaces, the fossa mandibularis is covered by fibrocartilage rather than hyaline cartilage. As a result, it is not as clearly delineated on the skull as other articular surfaces. The meatus acusticus externus lies just posterior to the fossa mandibularis. Trauma to the mandible may damage the meatus acusticus. *Note:* The fossa mandibularis is divided into two compartments (anterior and posterior), separated by the fissurae tympanosquamosa and petrotympanica. The posterior compartment is nonarticulatory, and the chorda tympani and arteria tympanica anterior are able to pass through this space without being compressed. The glenoid lobe of the glandula parotidea may also project into the posterior compartment.

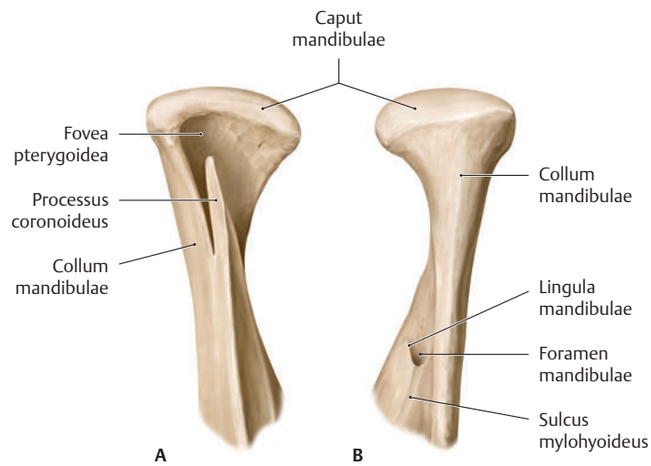


Fig. 6.14 **Processes of the mandibulae**

A Anterior view. **B** Posterior view. The head of the mandible not only is markedly smaller than the fossa articularis but also has a cylindrical shape. This shape increases the mobility of the caput mandibulae, as it allows rotational movements about a vertical axis (condylar–hinge axis).

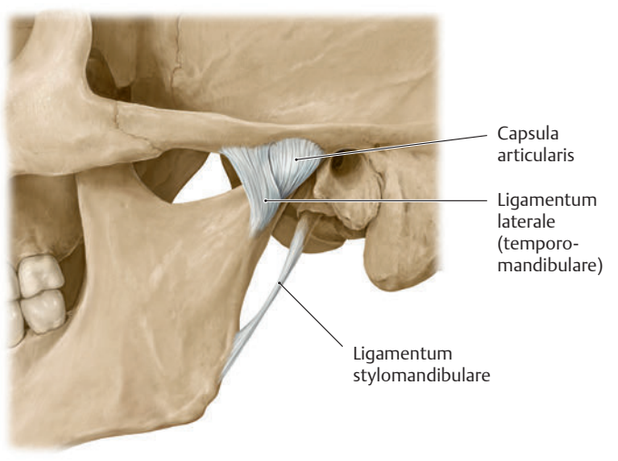


Fig. 6.15 **Ligaments of the left TMJ**

Lateral view. The TMJ is surrounded by a relatively lax capsule, which permits physiological dislocation during jaw opening. The joint is stabilized by three ligaments: ligamenta laterale (temporomandibulare), stylomandibulare, and sphenomandibulare (see **Fig. 6.16**). This lateral view demonstrates the strongest of these ligaments, the ligamentum laterale, which stretches over the capsule and is blended with it.

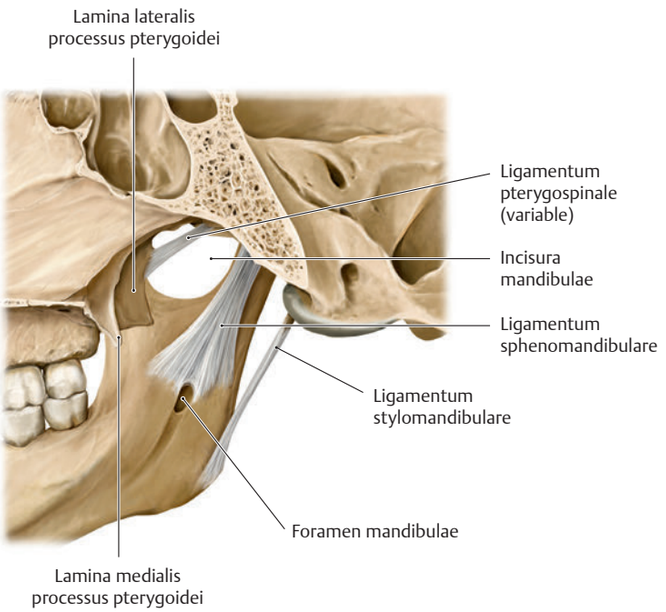


Fig. 6.16 **Ligaments of the right TMJ**
Medial view. The ligamentum sphenomandibulare can be identified in this view.

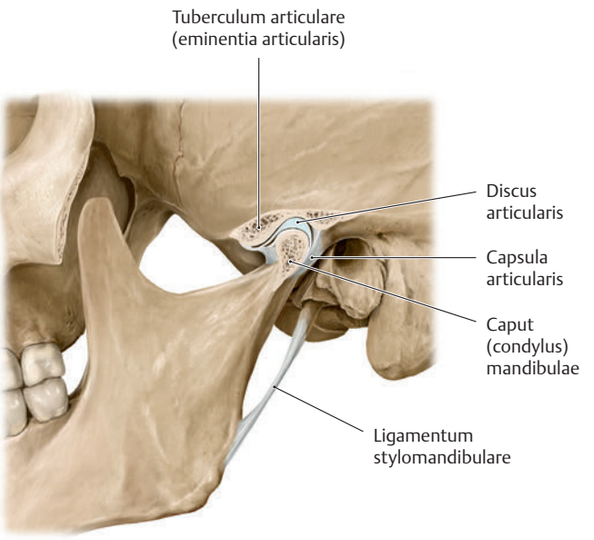


Fig. 6.17 **Opened left TMJ**
Lateral view. The capsule extends posteriorly to the fissura petrotympanica (not shown here). Interposed between the caput mandibulae and fossa mandibularis is the discus articularis, which is attached to the capsula articularis on all sides. *Note:* The discus articularis (meniscus) divides the TMJ into upper and lower compartments. Gliding (translational) movement occcurs in the upper compartment, hinge (rotational) movement in the lower compartment.

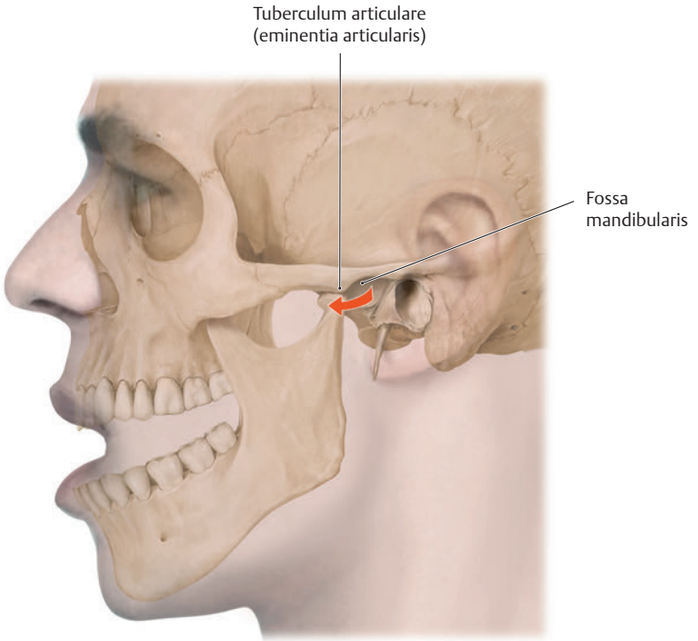


Fig. 6.18 **Dislocation of the TMJ**
The caput mandibulae may slide past the tuberculum articulare when the mouth is opened, dislocating the TMJ. This may result from heavy yawning or a blow to the opened mandible. When the joint dislocates, the mandible becomes locked in a protruded position and can no longer be closed. This condition is easily diagnosed clinically and is reduced by pressing on the mandibular row of teeth.

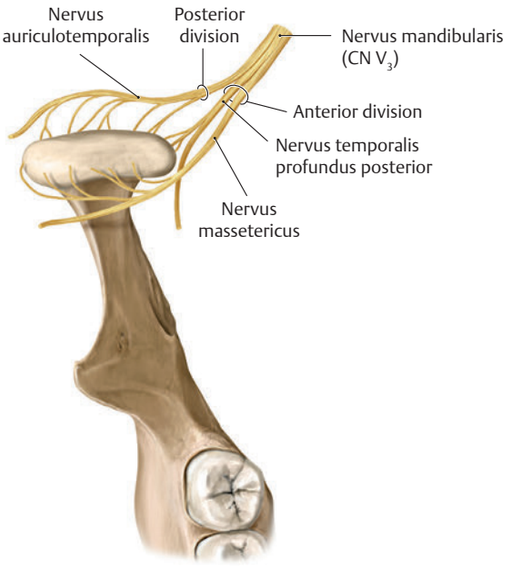


Fig. 6.19 **Sensory innervation of the TMJ capsule** (after Schmidt)
Superior view. The TMJ capsule is supplied by articular branches arising from three branches of the nervus mandibularis division of the nervus trigeminus (CN V_3):

- Nervus auriculotemporalis (posterior division of CN V_3)
- Nervus temporalis profundus posterior (anterior division of CN V_3)
- Nervus massetericus (anterior division of CN V_3)

Note: While the nervi massetericus and temporalis profundus posterior are generally considered to be motor nerves, they also innervate the TMJ.

Articulatio Temporomandibularis (TMJ): Biomechanics

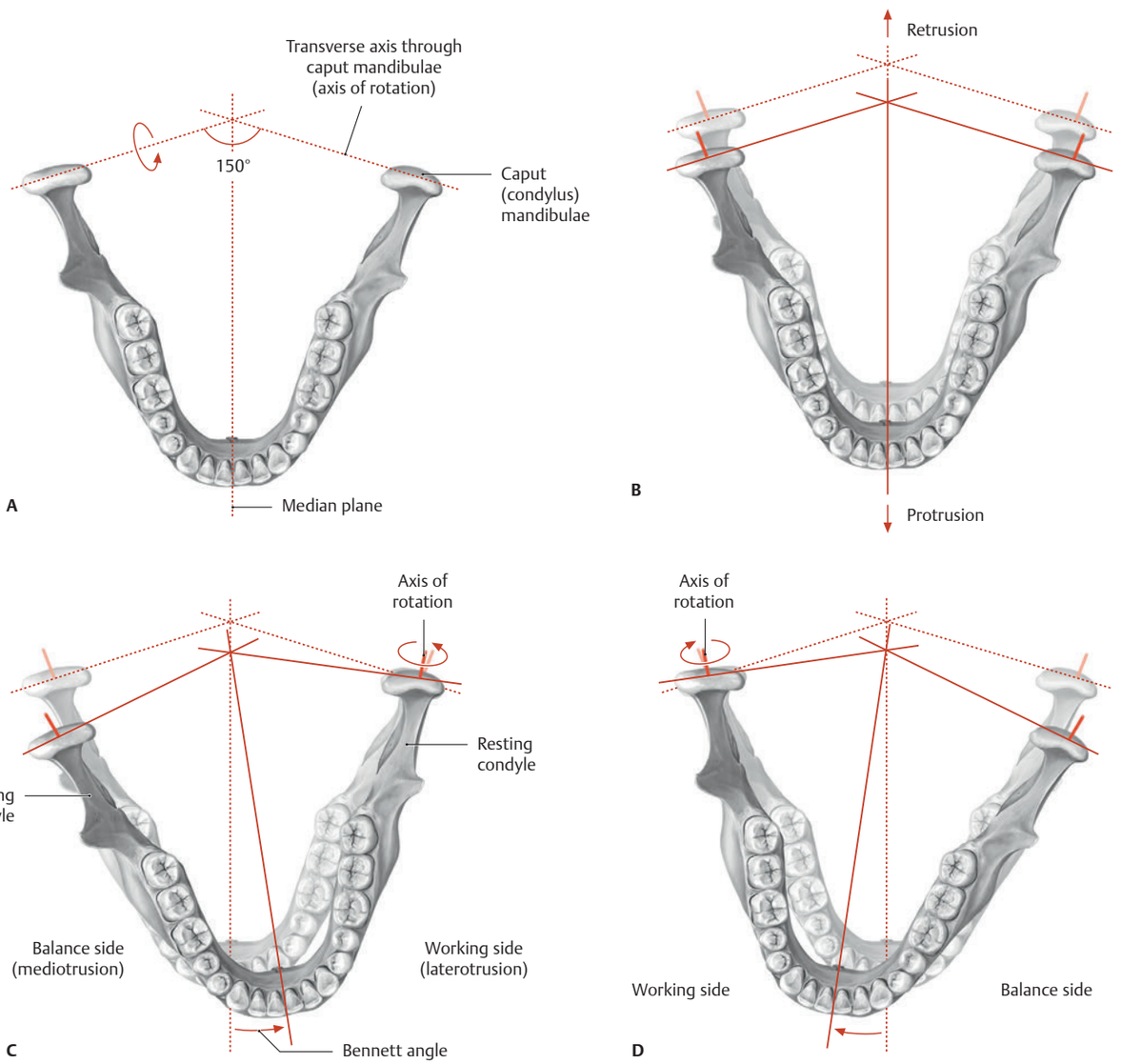


Fig. 6.20 **Movements of the mandibula in the TMJ**
Superior view. Most of the movements in the TMJ are complex motions that have three main components:

- Rotation (opening and closing the mouth)
- Translation (protrusion and retrusion of the mandibula)
- Grinding movements during mastication

A **Rotation.** The axis for joint rotation runs transversely through both heads of the mandibula. The two axes intersect at an angle of approximately 150 degrees (range of 110–180 degrees between individuals). During this movement the TMJ acts as a hinge joint (abduction/depression and adduction/elevation of the mandibula). In humans, pure rotation in the TMJ usually occurs only during sleep with the mouth slightly open (aperture angle up to approximately 15 degrees, see **Fig. 6.21B**). When the mouth is opened past 15 degrees, rotation is combined with translation (gliding) of the caput mandibulae.

B **Translation.** In this movement the mandibula is advanced (protruded) and retracted (retruded). The axes (condylar–hinge axes) for this movement are parallel to the median axes through the center of the capita mandibulae.

C **Grinding movements in the left TMJ.** In describing these lateral movements, a distinction is made between the "resting condyle" and the "swinging condyle." The resting condyle on the left working side rotates about an almost vertical axis through the caput mandibulae (also a rotational axis), whereas the swinging condyle on the right balance side swings forward and inward in a translational movement. The lateral excursion of the mandibula is measured in degrees and is called the Bennett angle. During this movement the mandible moves in laterotrusion on the working side and in mediotrusion on the balance side.

D **Grinding movements in the right TMJ.** Here, the right TMJ is the working side. The right resting condyle rotates about an almost vertical axis, and the left condyle on the balance side swings forward and inward.

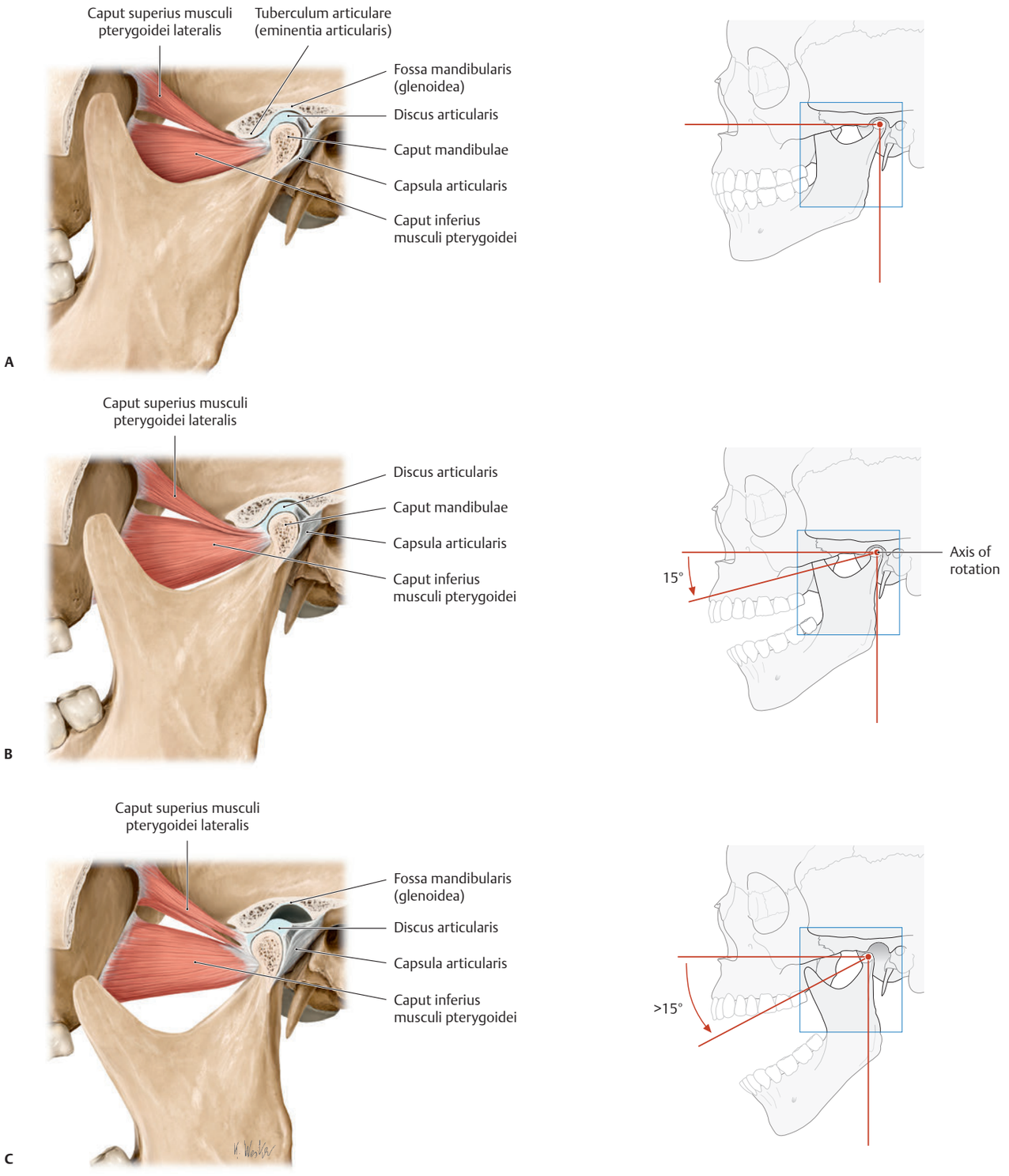


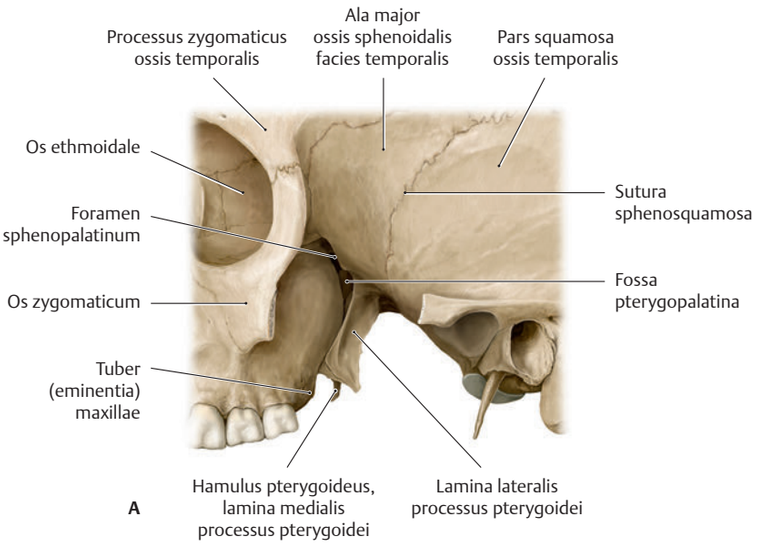
Fig. 6.21 **Movements of the TMJ**
Left lateral view. Each drawing shows the left TMJ (including the discus articularis and capsula articularis) and the musculus pterygoideus lateralis. *Note:* The gap between the heads of the musculus pterygoideus lateralis is exaggerated. Each schematic diagram at right shows the corresponding axis of joint movement. The muscle, capsule, and disk form a functionally coordinated musculo-disco-capsular system and work closely together when the mouth is opened and closed.

A **Mouth closed, teeth in occlusion.** When the mouth is in the closed position with teeth in occlusion, the caput (condylus) mandibulae maintains its contact with the articular disk, and the space of the upper compartment is maintained between the discus articularis and the ossa mandibularis (glenoidea) of the os temporale.

B **Mouth opened to 15 degrees.** Up to 15 degrees of abduction, the caput mandibulae remains in the fossa mandibularis.

C **Mouth opened past 15 degrees.** At this point the caput mandibulae glides (translates) forward onto the tuberculum articulare (eminentia articularis). The joint axis that runs transversely through the caput mandibulae is shifted forward. The discus articularis is pulled forward by the caput superius of the musculus pterygoideus lateralis, and the caput (condylus) mandibulae is drawn forward by the caput inferius of that muscle.

Fossa Pterygopalatina: Overview



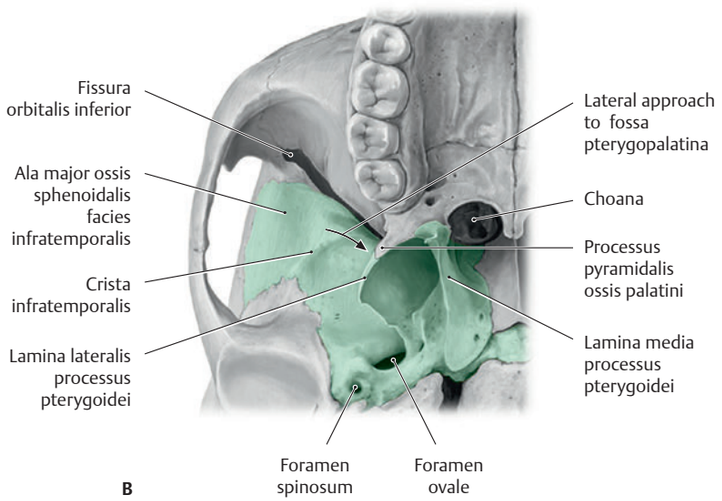


Fig. 6.22 **Fossa pterygopalatina**
A Left lateral view of left fossa infratemporalis and fossa pterygopalatina. **B** Inferior view of right fossa infratemporalis and lateral approach to fossa pterygopalatina. The fossa pterygopalatina is a crossroads between the orbita, cavitas nasi, cavitas oris, pars nasalis pharyngis, and fossa cranii media. It is traversed by many nerves and vessels supplying these structures. The fossa pterygopalatina is continuous laterally with the fossa infratemporalis through the pterygopalatine fissure. The lateral approach through the fossa infratemporalis is used in surgical operations on tumors of the fossa pterygopalatina (e.g., nasopharyngeal fibroma).

Table 6.8 **Borders and openings of the pterygopalatine fossa**

Border	Structure	Foramen/fissures/canals
Superior	Os sphenoidale (ala major)	Fissura orbitalis inferior (runs beside os sphenoidale in roof of fossa pterygopalatina)
Inferior	Canalis palatinus major	Canalis palatinus major (continuous with fossa pterygopalatina)
Anterior	Maxilla (facies infratemporalis [posterior])	
Posterior	Os sphenoidale, root of the processus pterygoideus	Foramen rotundum
		Canalis pterygoideus
		Canalis palatovaginalis
Medial	Os palatinum (lamina perpendicularis)	Foramen sphenopalatinum
Lateral	Fissura pterygomaxillaris	Fissura pterygomaxillaris

***Fig. 6.23* Communications of the fossa pterygopalatina**
Left lateral view of left fossa (detail from **Fig. 6.22A**). The fossa pterygopalatina contains the ganglion pterygopalatinum, the parasympathetic ganglion of CN VII that is affiliated with the nervus maxillaris (CN V_2, sensory). Sensory fibers from the face, maxillary dentition, cavitas nasi, cavitas oris, pars nasalis pharyngis, and sinus paranasales pass through the ganglion without synapsing and enter the fossa cranii media as the maxillary nerve (CN V_2). These sensory fibers also serve as "scaffolding" for the peripheral distribution of postganglionic autonomic parasympathetic fibers from the ganglion pterygopalatinum and postganglionic sympathetic fibers derived from the plexus caroticus internus. See **Table 4.23** for a complete treatment of the nervus maxillaris and ganglion pterygopalatinum.

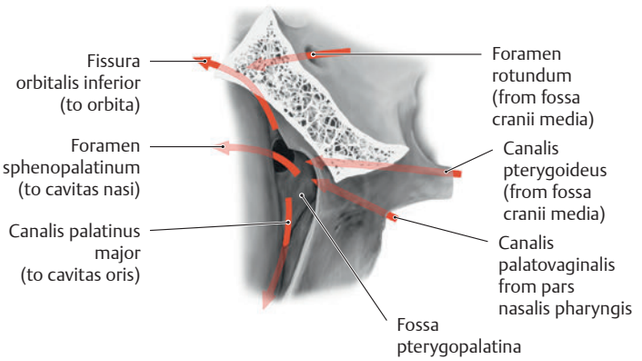


***Table 6.9* Communications of the fossa pterygopalatina**

Communication	Direction	Via	Transmitted structures
Fossa cranii media	Posterosuperiorly	Foramen rotundum	• Nervus maxillaris (CN V_2)
Fossa cranii media	Posteriorly in anterior wall of foramen lacerum	Canalis pterygoideus	• Nervus canalis pterygoidei, formed from: ◦ Nervus petrosus major (preganglionic parasympathetic fibers from CN VII) ◦ Nervus petrosus profundus (postganglionic sympathetic fibers from Plexus caroticus internus) • Arteria canalis pterygoidei • Venae canalis pterygoidei
Orbita	Anterosuperiorly	Fissura orbitalis inferior	• Branches of nervus maxillaris (CN V_2): ◦ Nervus infraorbitalis ◦ Nervus zygomaticus • Arteria and vena infraorbitalis • Communicating veins between vena ophthalmica inferior and plexus pterygoideus
Cavitas nasi	Medially	Foramen sphenopalatinum	• Nervus nasopalatinus (CN V_2), rami nasales posteriores superiores laterales and mediales • Arteria and vena sphenopalatina
Cavitas oris	Inferiorly	Canalis palatinus major (foramen palatinum majus)	• Nervus palatinus major (CN V_2) and arteria palatina major • Branches that emerge through lesser palatine canals: ◦ Nervi palatini minores (CN V_2) and arteriae palatinae minores
Pars nasalis pharyngis	Inferoposteriorly	Canalis palatovaginalis	• CN V_2, rami pharyngeales (arteria maxillaris)
Fossa infratemporalis	Laterally	Fissura pterygomaxillaris	• Arteria maxillaris (third portion) • Rami alveolares superiores posteriores, Arteria alveolaris superior posterior

Topography of the Fossa Pterygopalatina

The fossa pterygopalatina is a small inverted pyramidal space just inferior to the apex of the orbita. It is continuous with the fossa infratemporalis through the fissura pterygomaxillaris. The fossa pterygopalatina is a crossroads for neurovascular structures traveling between the fossa cranii media, orbita, cavitas nasi, and cavitas oris.

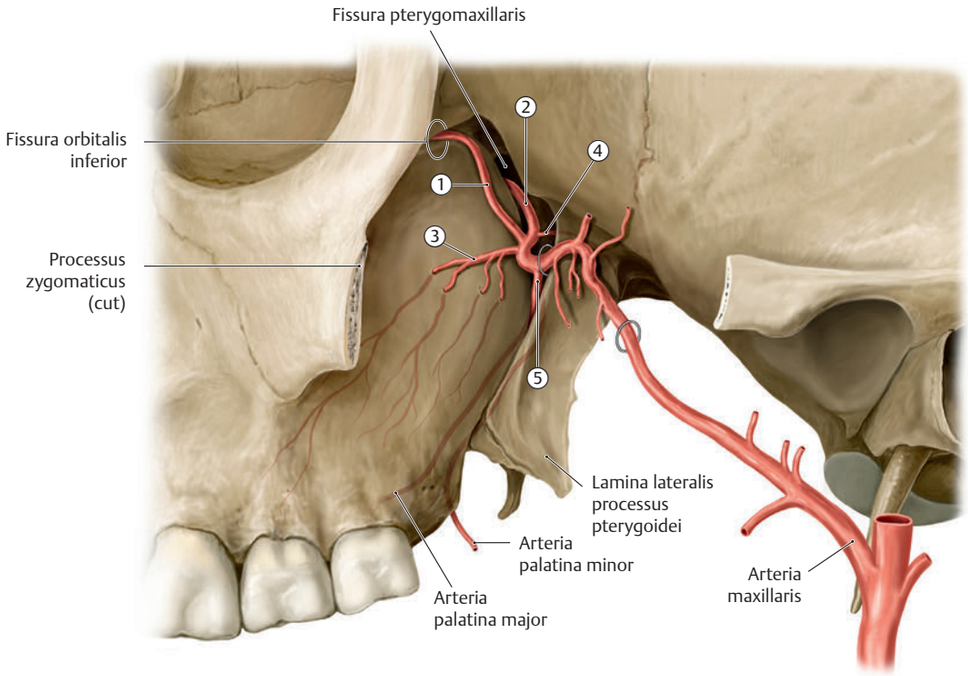


Fig. 6.24 **Arteries in the fossa pterygopalatina**
Left lateral view into area. The arteria maxillaris passes either superficial or deep to the musculus pterygoideus lateralis in the fossa infratemporalis and enters the fossa pterygopalatina through the fissura pterygomaxillaris.

Table 6.10 **Branches of the arteria maxillaris within the fossa pterygopalatina**

Part of maxillary artery	Artery		Distribution
Pterygopalatine part	① Arteria infraorbitalis		Cheek, upper lip, nose, lower eyelid
		Arteriae alveolares superiores anteriores	Maxillary anterior teeth (to premolars), sinus maxillaris
	② Arteria sphenopalatina	Arteriae nasales posteriores laterales	Lateral wall of cavitas nasi, choanae, sinus paranasales (sinus frontalis, sinus maxillaris, sinus sphenoidalis, and cellulae ethmoidales)
		Rami septales posteriores	Septum and conchae nasi
	③ Arteria alveolaris superior posterior		Dentes maxillares premolares, molares, gingiva, sinus maxillaris
	④ Arteria canalis pterygoidei		Tuba auditiva, cavitas tympani, upper pharynx
	⑤ Arteria palatina descendens	Arteria palatina major	Palatum durum, cavitas nasi (meatus nasi inferior), gingiva maxillaris
		Arteriae palatinae minores	Palatum molle, tonsilla palatina, pharyngeal wall

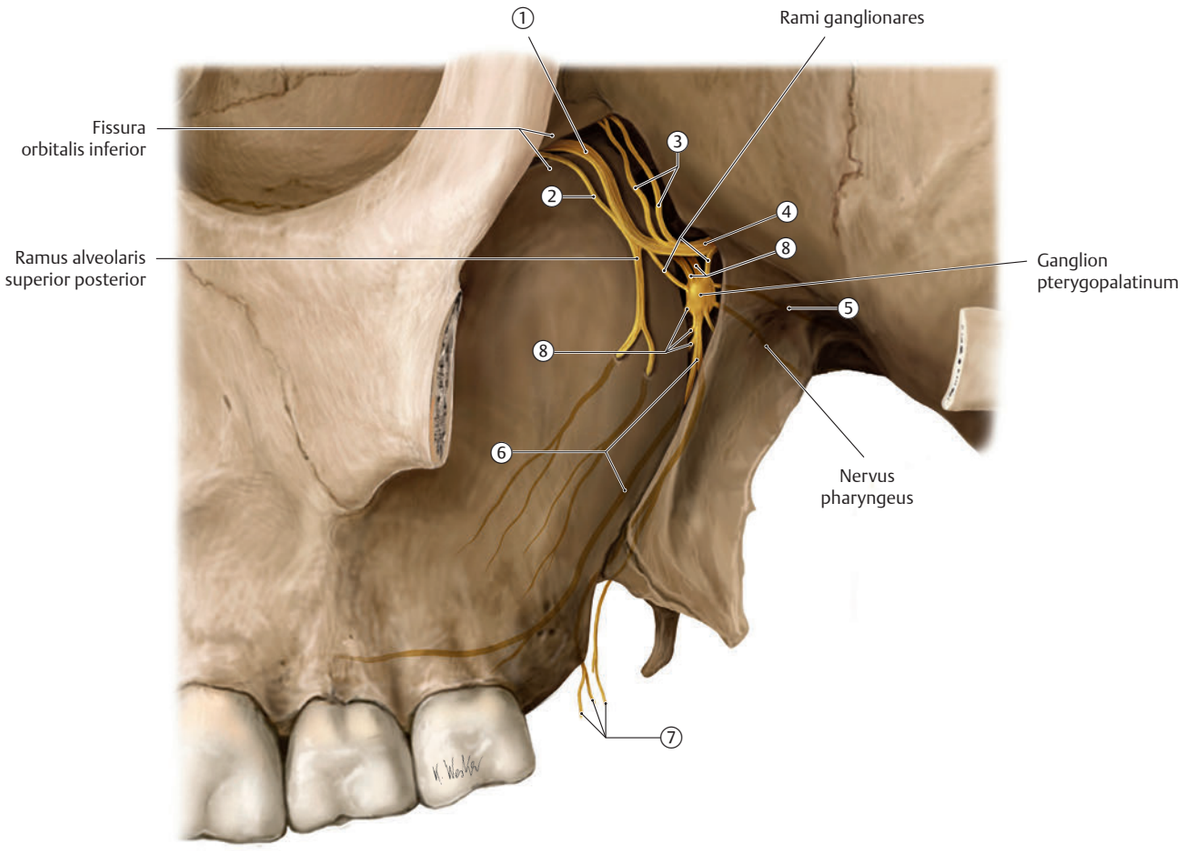


Fig. 6.25 **Nerves in the fossa pterygopalatina**
Left lateral view.
The nervus maxillaris division of the nervus trigeminus (CN V_2) passes from the fossa cranii media through the foramen rotundum into the fossa pterygopalatina (see **Table 6.11**). The parasympathetic ganglion pterygopalatinum receives presynaptic fibers from the nervus petrosus major (the parasympathetic root of the nervus intermedius branch of the nervus facialis). The preganglionic fibers of the ganglion pterygopalatinum synapse with ganglion cells that innervate the glandulae lacrimales, small palatal, and small nasal. The sympathetic fibers of the nervus petrosus profundus (radix sympathica) pass through the ganglion pterygopalatinum without synapsing.

Table 6.11 **Nerves that emerge from fossa pterygopalatina***

Transmitted nerves	Distribution
① Nervus infraorbitalis	Sensory to lower eyelid, sinus maxillaris, and dentes incisivi, canini, and premolares maxillares.
② Nervus zygomaticus	Sensory to skin of the temple (ramus zygomaticotemporalis) and cheek (ramus zygomaticofacialis)
③ Rami orbitales (from CN V_2)	Sensory to orbital periosteum, sinus sphenoidalis, and cellulae ethmoidales
④ Nervus maxillaris (CN V_2)	Gives off only sensory branches within fossa pterygopalatina
⑤ Nervus canalis pterygoidei (vidian n.)	• Nervus petrosus major carries preganglionic parasympathetic fibers to the ganglion pterygopalatinum (from CN VII); • Nervus petrosus profundus carries postganglionic sympathetic fibers to the ganglion pterygopalatinum
⑥ Nervus palatinus major	Sensory to gingiva, mucosa, and glands of the posterior two thirds of the hard palate
⑦ Nervi palatini minores	Sensory to soft palate, tonsillae palatinae, and uvula
⑧ Rami nasales posteriores superiores mediales and laterales and rami nasales posteriores inferiores (from nervus nasopalatinus, CN V_2)	Sensory to the posterosuperior cavitas nasi; medial branches also sensory to posterior nasal roof and septum; lateral branches also sensory to cellulae ethmoides posteriores and mucosa overlying the conchae nasales superior and media

*Because the fossa pterygopalatina contains all branches of CN V_2, it is the site of needle placement for a maxillary division block (see p. 478)

Nose: Nasal Skeleton

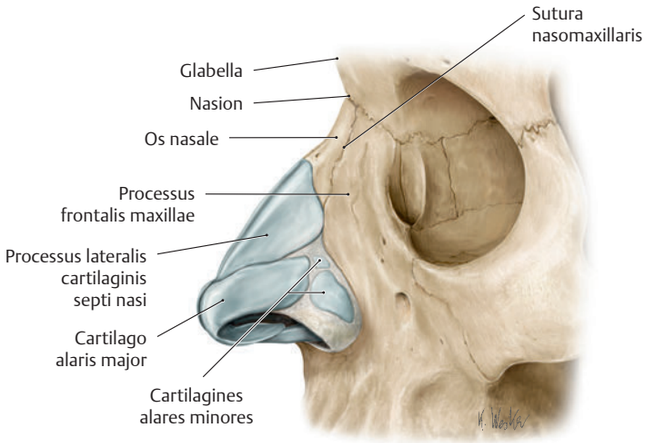


Fig. 7.1 **Skeleton of the nasus externus**
Left lateral view. The skeleton of the nose is composed of bone, cartilage, and connective tissue. Its upper portion is bony and frequently involved in midfacial fractures, whereas its lower, distal portion is cartilaginous and therefore more elastic and less susceptible to injury. The proximal lower portion of the nostrils (alae) is composed of connective tissue with small embedded pieces of cartilage. The processus lateralis cartilaginis septi nasi is a winglike lateral expansion of the pars cartilaginea of the septi nasi rather than a separate piece of cartilage.

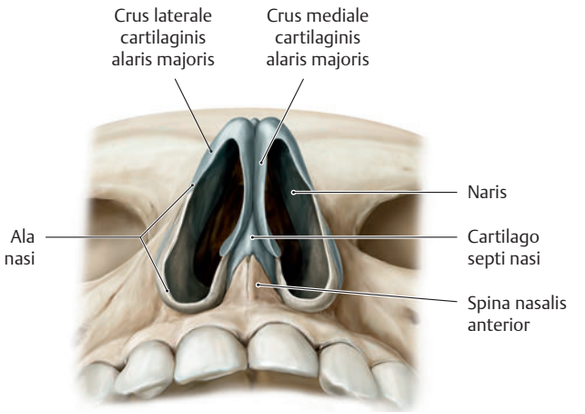


Fig. 7.2 **Nasal cartilage**
Inferior view. Viewed from below, each of the cartilagines alares majores is seen to consist of a crus mediale and crus laterale. This view also displays the two nares, which open into the cavitates nasi. The right and left cavitates nasi are separated by the septum nasi, whose inferior cartilaginous portion is just visible in the diagram.

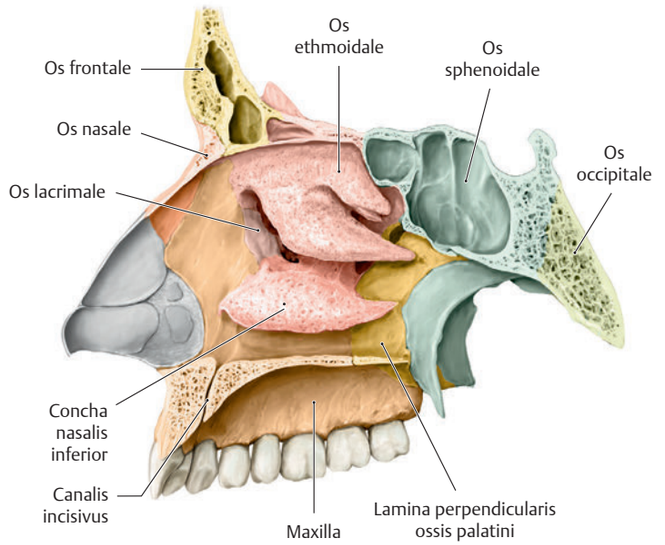


Fig. 7.3 **Bones of the lateral wall of the right cavitas nasi**
Left lateral view. The lateral wall of the right cavitas nasi is formed by seven bones: the maxilla, os nasale, os ethmoidale, concha nasalis inferior, os palatinum, os lacrimale, and os sphenoidale. Of the conchae nasi, only the inferior is a separate bone; the conchae media and superior are parts of the os ethmoidale.

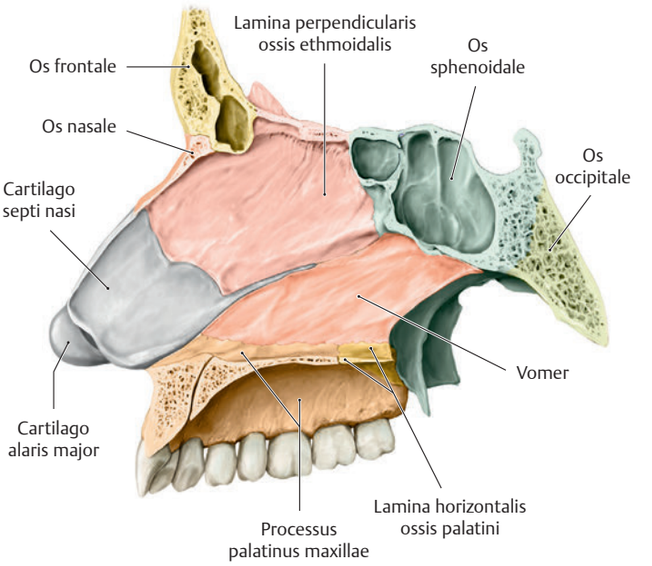


Fig. 7.4 **Bones of the septum nasi**
Parasagittal section. The Septum nasi is formed by six bones. The os ethmoidale and vomer are the major components of the septum. The os sphenoidale, os palatinum, maxilla, and os nasale (roof of the septum) contribute only small bony projections to the septum nasi.

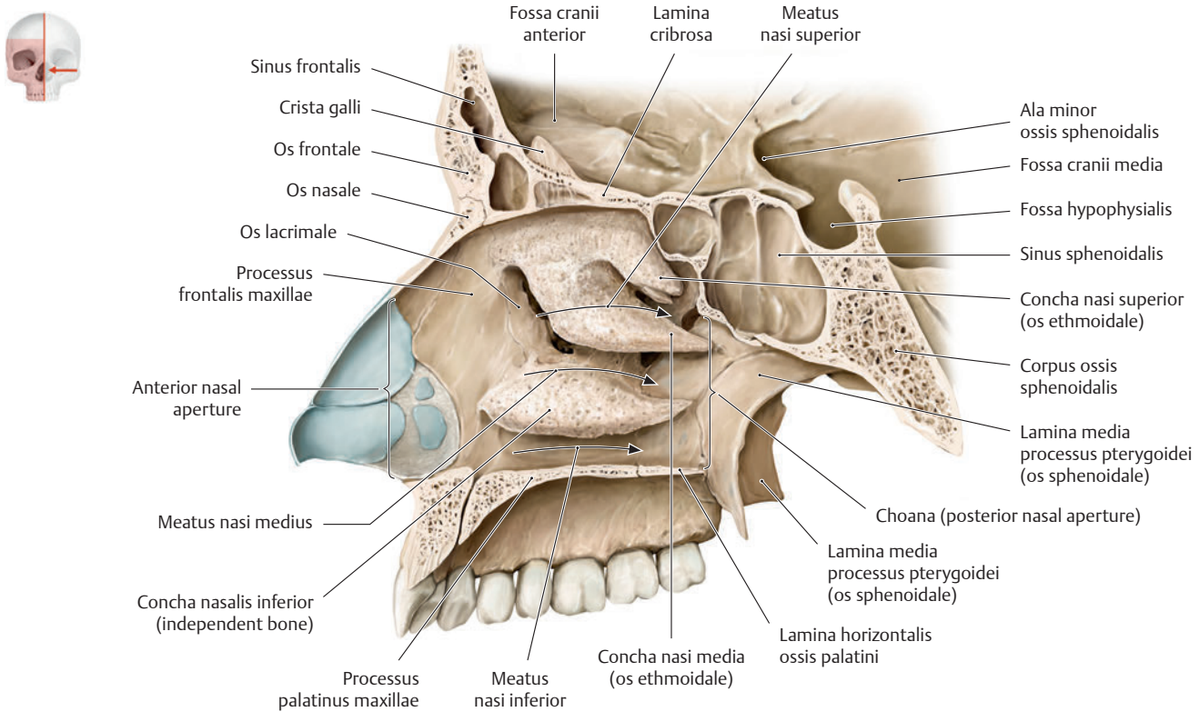


Fig. 7.5 **Lateral wall of the right cavitas nasi**
Medial view. Air enters the cavitas nasalis ossea through the anterior nasal aperture and travels through the three nasal passages: the meatus nasi superior, meatus nasi medius, and meatus nasi inferior, which are the spaces inferolateral to the conchae superior, media, and inferior, respectively. Air leaves the nose through the choanae (posterior nasal apertures), entering the pars nasalis pharyngis.

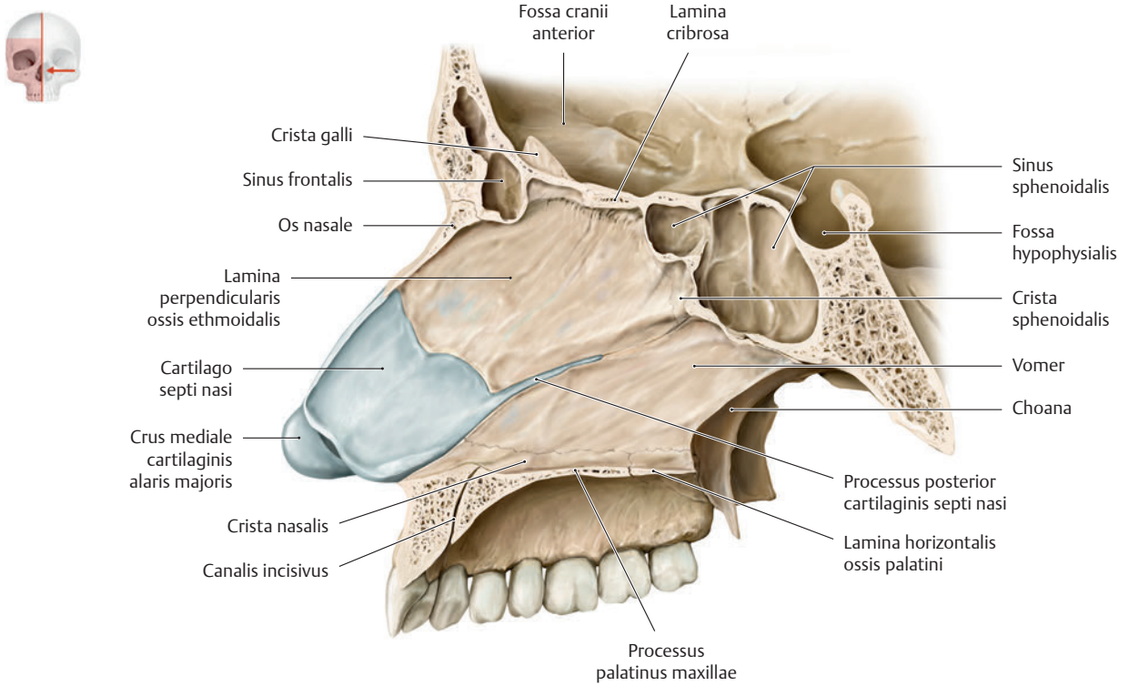


Fig. 7.6 **Septum nasi**
Parasagittal section viewed from the left. The left lateral wall of the cavitas nasi has been removed with the adjacent bones. The septum nasi consists of an anterior cartilago septi nasi and a posterior bony part composed of several bones. The processus posterior cartilaginis septi nasi extends deep into the bony septum. Deviations of the septum nasi are common and may involve the cartilaginous part of the septum, the bony part, or both. Cases in which the septal deviation is sufficient to cause obstruction of nasal breathing can be surgically corrected.

Overview of the Cavitas Nasi & Sinus Paranasales

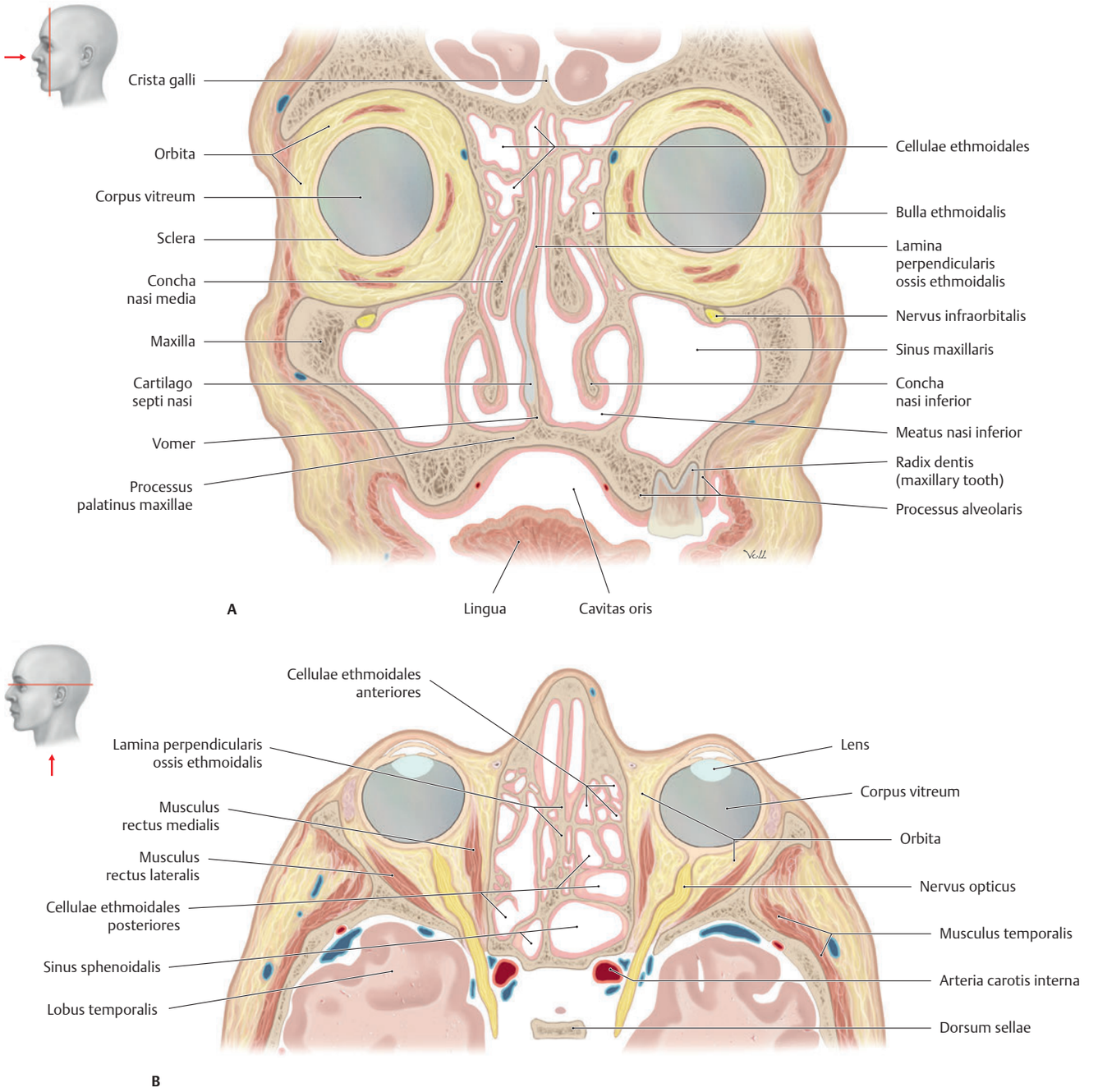


Fig. 7.7 **Overview of the nose and sinus paranasales**
A Coronal section through cavitas nasi, anterior view. **B** Transverse section, inferior view.
The cavitates nasi and sinus paranasales are arranged in pairs. The left and right cavitates nasi are separated by the septum nasi and have an approximately triangular shape. Below the base of the triangle is the cavitas oris. Note the relations of the nervus infraorbitalis and maxillary dentition to the sinus maxillaris.
The close proximity of the roots of the maxillary teeth (canine to second molar) to the sinus maxillaris (antrum) is very significant in clinical dentistry. Sinus pathology, for example, acute maxillary sinusitis due to an upper respiratory infection (URTI), can often be confused as dental pain originating from these teeth. Diagnosis is made by exclusion of dental pathology and observation of URTI symptoms, such as nasal discharge and stuffiness. Furthermore, the pain of acute maxillary sinusitis is often worsened by bending the head forward. There would also be tenderness on palpation of the cheeks.
The close proximity is also significant because the roots or the entire tooth can be displaced into the sinus maxillaris during extractions, requiring surgical removal (see **Fig. 7.17**).
Extracted upper molars may also cause an oro-antral fistula, an abnormal communication between the cavitas oris and the sinus maxillaris. Post-extraction reflux of fluids into the nose or minor nosebleeds should raise the dentist's index of suspicion of this condition. Diagnosis is confirmed by getting the patient to hold their nose and blow: air bubbles will be seen at the tooth socket. Small oro-antral fistulas close spontaneously; others require suturing of the mucosal flap.

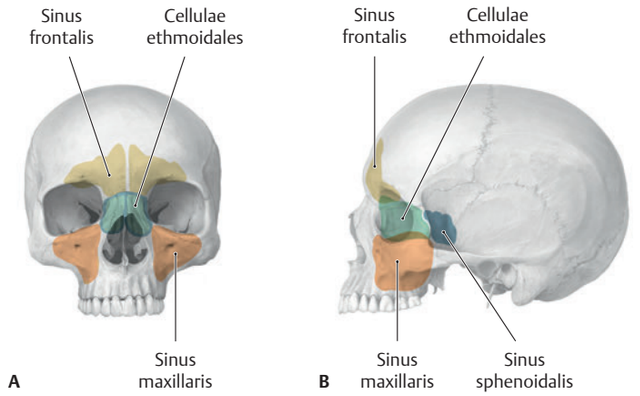


Fig. 7.8 **Projection of the sinus paranasales onto the skull**
A Anterior view. **B** Left lateral view.
The sinus paranasales are air-filled cavities that reduce the weight of the skull. They are subject to inflammation that may cause pain over the affected sinus (e.g., frontal headache due to frontal sinusitis). Knowing the location and sensory supply of the sinuses is helpful in making the correct diagnosis.

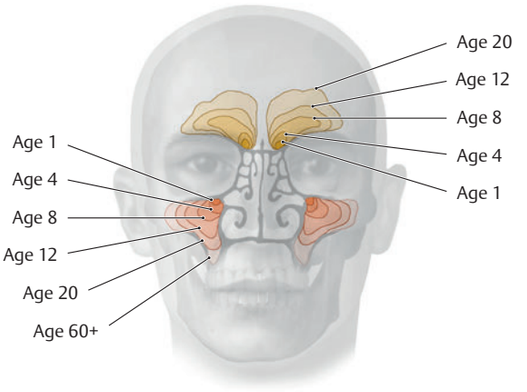
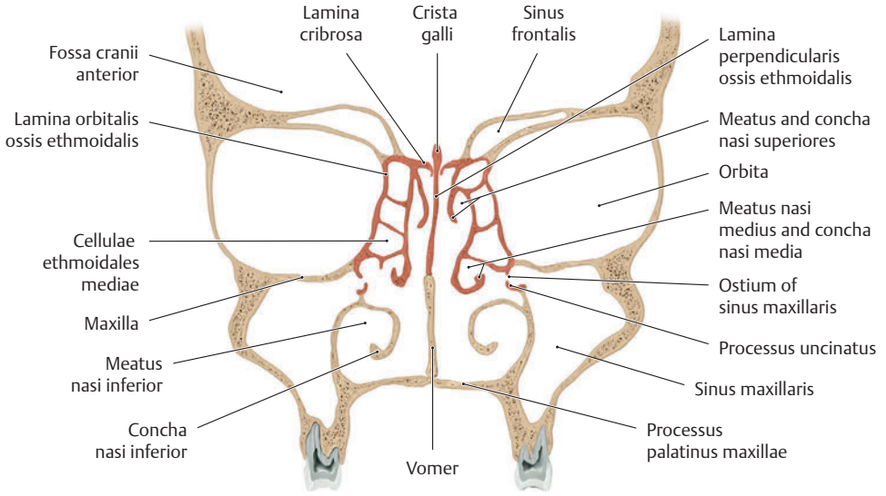


Fig. 7.9 **Pneumatization of the sinus maxillaris and frontalis**
Anterior view. The sinus frontalis and maxillaris develop gradually during the course of cranial growth (pneumatization), unlike the cellulae ethmoidales, which are already pneumatized at birth. As a result, sinusitis in children is most likely to involve the cellulae ethmoidales (with risk of orbital penetration: red, swollen eye).



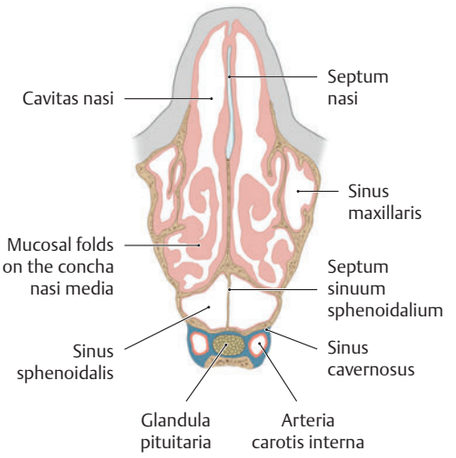


Fig. 7.10 **Bony structure of the sinus paranasales**
Anterior view. The central structure of the *sinus paranasales* is the os ethmoidale (red). Its lamina cribrosa forms a portion of the anterior skull base. The sinus frontalis and maxillaris are grouped around the os ethmoidale. The meati nasi inferior, medius, and superior of the cavitas nasi are bounded by the accordingly named conchae. The bony ostium of the sinus maxillaris opens into the meatus nasi medius, lateral to the concha nasi media. Below the concha nasi media and above the sinus maxillaris ostium is the bulla ethmoidalis, which contains the cellulae ethmoidales mediae. At its anterior margin is a bony hook, the processus uncinatus, which bounds the sinus maxillaris ostium anteriorly. The concha nasi media is a useful landmark in surgical procedures on the sinus maxillaris and anterior os ethmoidale. The lateral wall separating the os ethmoidale from the orbita is the paper-thin lamina orbitalis (= lamina papyracea). Inflammatory processes and tumors may penetrate this thin plate in either direction. *Note:* The maxilla forms the floor of the orbita and roof of the sinus maxillaris. In addition, roots of the maxillary dentition may project into the sinus maxillaris.

Fig. 7.11 **Cavitas nasi and sinus paranasales**
Transverse section viewed from above. The mucosal surface anatomy has been left intact to show how narrow the nasal passages are. Even relatively mild swelling of the mucosa may obstruct the cavitas nasi, impeding aeration of the sinus paranasales.
The glandula pituitaria, located behind the sinus sphenoidalis in the fossa hypophysialis, is accessible via transnasal surgical procedures.

Cavitas Nasi

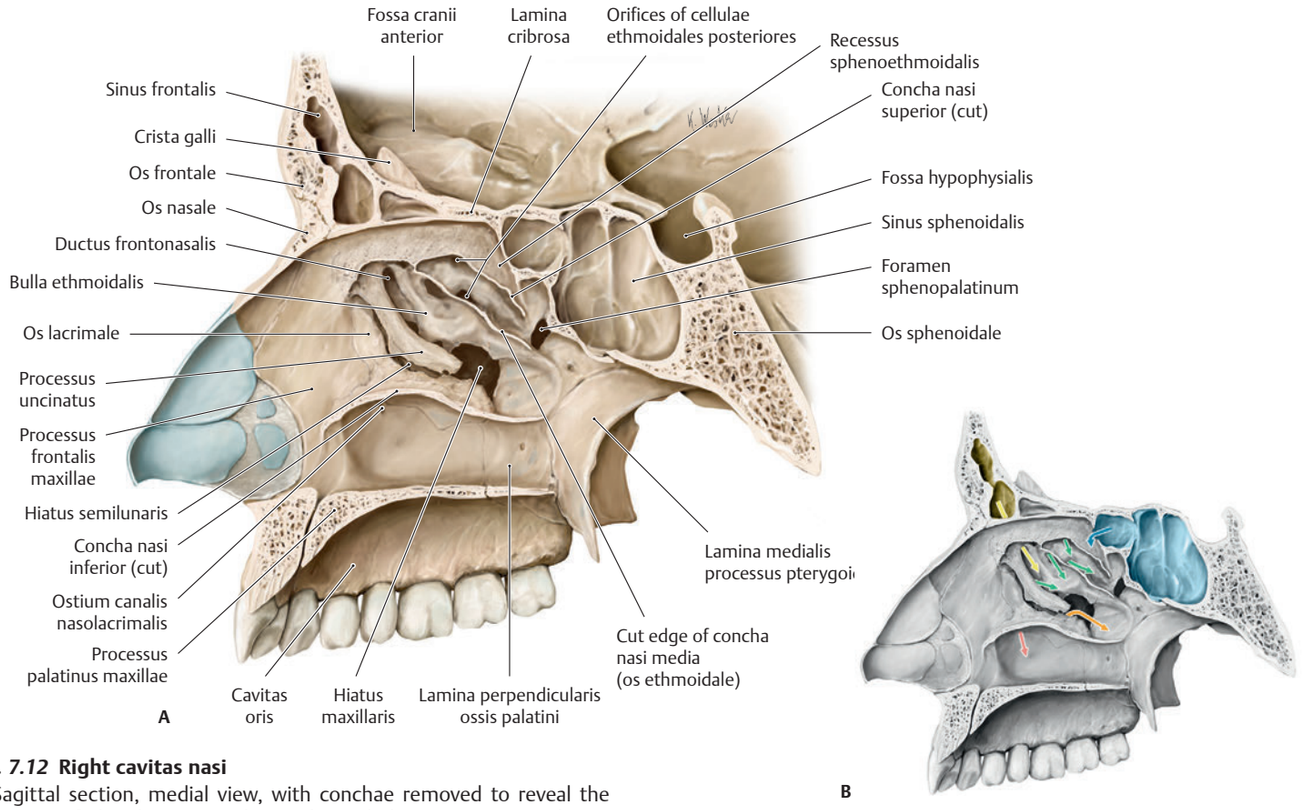
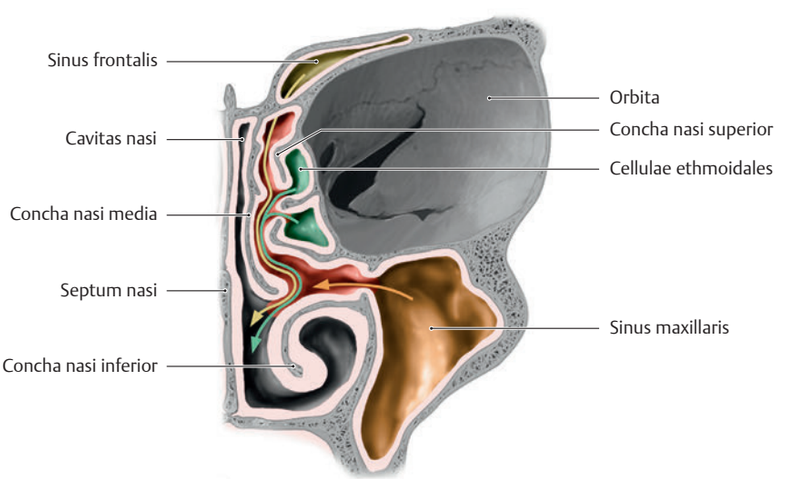


Fig. 7.12 **Right cavitas nasi**
A Sagittal section, medial view, with conchae removed to reveal the openings of the ductus nasolacrimalis and the sinus paranasales. **B** Drainage of the ductus nasolacrimalis and the sinus paranasales (see Table 7.1); arrows indicate flow of mucosal secretions into the cavitas nasi.

Table 7.1 **Drainage of the ductus nasolacrimalis and the sinus paranasales**

Duct/Sinuses	Via	Drains to
Ductus nasolacrimalis (red)	Canalis nasolacrimalis	Meatus nasi inferior
Sinus frontalis (yellow)	Ductus frontonasalis	Meatus nasi medius
Sinus maxillaris (orange)	Direct	Meatus nasi medius
Cellulae ethmoidales anteriores and mediae (green)		
Cellulae ethmoidales posteriores (green)	Direct	Meatus nasi superior
Sinus sphenoidalis (blue)	Direct	Recessus sphenoethmoidalis

Fig. 7.13 **Osteomeatal unit (complex)**
Coronal section. Arrows indicate flow of mucosal secretions. The osteomeatal unit (complex) is that part of the meatus nasi medius into which the sinus frontalis and maxillaris drain along with the cellulae ethmoidales anteriores and mediae. When the mucosa (ciliated respiratory epithelium) in the cellulae ethmoidales (green) becomes swollen due to inflammation (sinusitis), it blocks the flow of secretions from the sinus frontalis (yellow) and sinus maxillaris (orange) in the osteomeatal unit (red). Because of this blockage, microorganisms also become trapped in the other sinuses, where they may incite an inflammation. Thus, whereas the anatomical focus of the disease lies in the cellulae ethmoidales, inflammatory symptoms are also manifested in the sinus frontalis and maxillaris. In patients with *chronic sinusitis*, the narrow sites can be surgically widened to establish an effective drainage route.



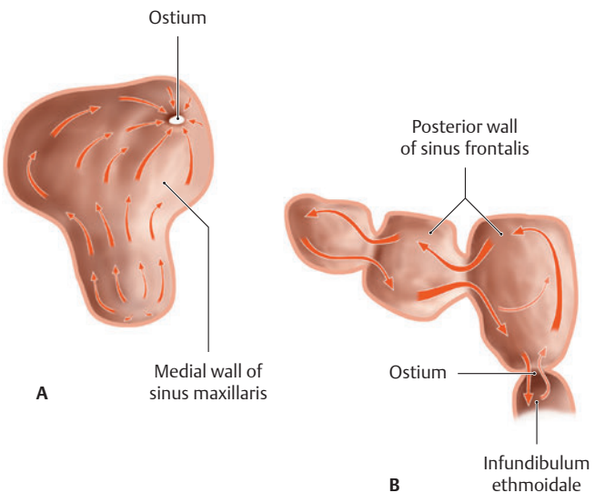


Fig. 7.14 **Ciliary beating and fluid flow in the right sinus maxillaris and frontalis**
Schematic coronal sections of the right sinus maxillaris (**A**) and sinus frontalis (**B**), anterior view.
Beating of the cilia produces a flow of fluid in the sinus paranasales that is always directed toward the sinus ostium. This clears the sinus of particles and microorganisms that are trapped in the mucous layer. If the ostium is obstructed due to swelling of the mucosa, inflammation may develop in the affected sinus (*sinusitis*). This occurs most commonly in the osteomeatal complex of the meatus nasi medius.

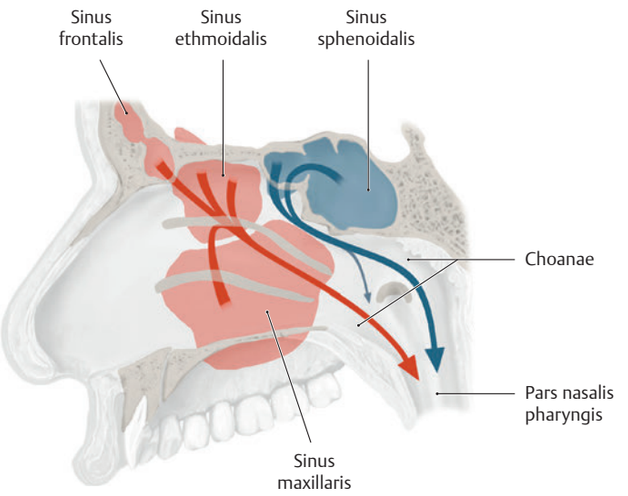


Fig. 7.15 **Normal drainage of secretions from the sinus paranasalis**
Left lateral view. The beating cilia propel the mucous blanket over the cilia and through the choana into the pars nasalis pharyngis, where it is swallowed.

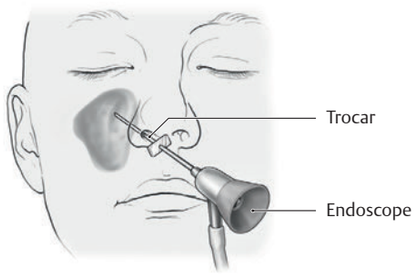


Fig. 7.16 **Endoscopy of the sinus maxillaris**
Anterior view. The sinus maxillaris is not accessible to direct inspection and must therefore be examined with an endoscope. To enter the sinus maxillaris, the examiner pierces the thin bony wall below the inferior concha with a trocar and advances the endoscope through the opening. The scope can then be angled and rotated to inspect all of the mucosal surfaces. Attachment of a suction device also facilitates the drainage of secretions. Drainage of the sinus maxillaris can also be achieved via the Caldwell-Luc procedure (see **Fig. 7.17**).

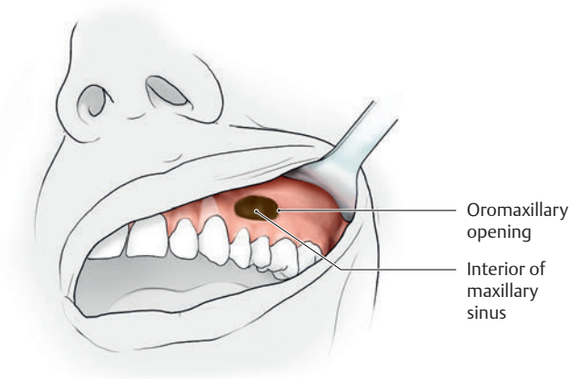
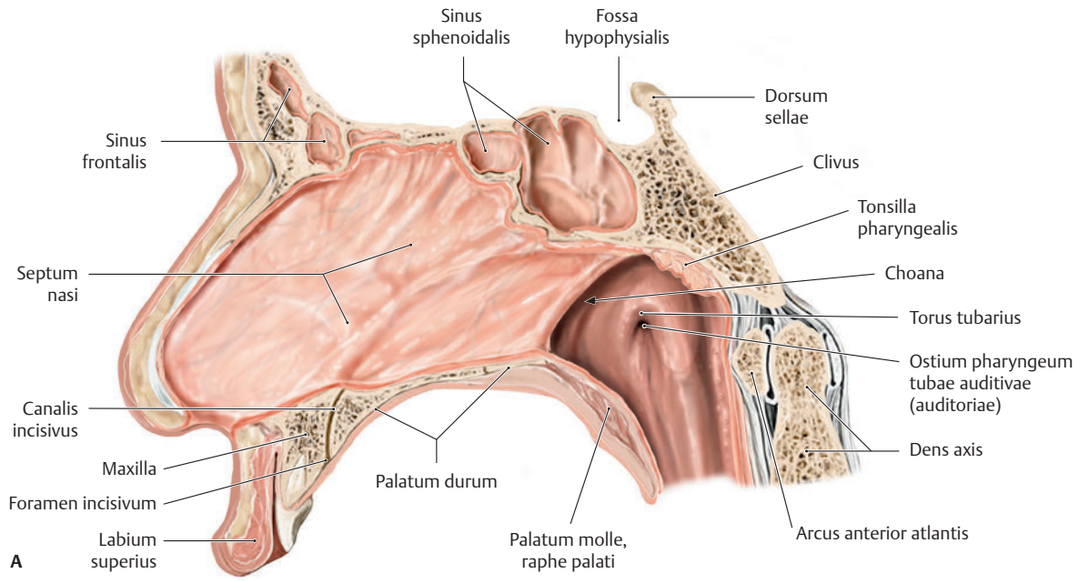
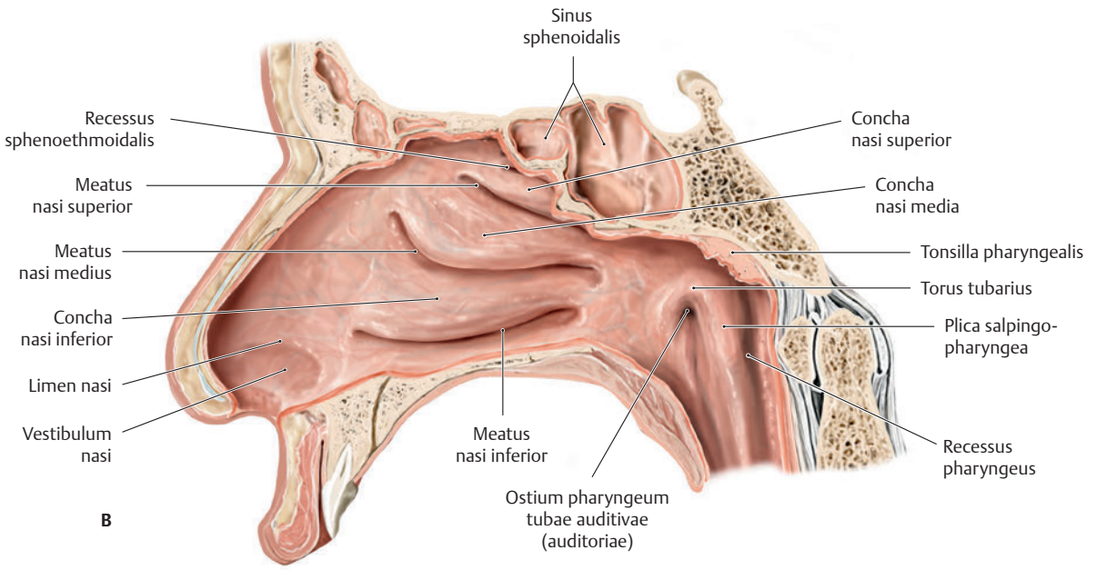


Fig. 7.17 **Caldwell-Luc Procedure**
In the Caldwell-Luc procedure, a window (fenestration) is created in the anterior wall of the sinus maxillaris. It is used to remove teeth or tooth roots that have been displaced during extractions (see **Fig 7.7**); to remove cysts, polyps, tumors, and other foreign bodies; to close oro-antral fistulas; to reduce facial fractures; and to drain the sinus (rare now due to endoscopy). It can also be used to gain access to the cellulae ethmoidales, the sinus sphenoidalis, and the fossa pterygomaxillaris (which lies behind the sinus maxillaris).

Mucosa of the Cavitas Nasi





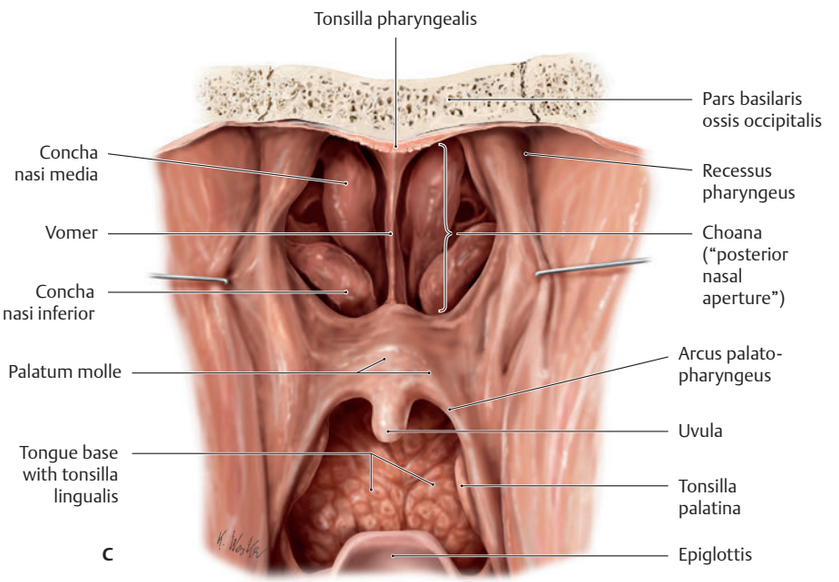


Fig. 7.18 **Mucosa of the cavitas nasi**
A Mucosa of the septum nasi, parasagittal section viewed from the left side. **B** Mucosa of the right lateral nasal wall, viewed from the left side. **C** Posterior view through the choanae into the cavitas nasi.
Although the medial wall of the cavitas nasi is smooth, its lateral wall is raised into folds by the three conchae (conchae superior, media, and inferior), which increase the surface area of the cavitas nasi, enabling it to warm and humidify the inspired air more efficiently. They also create turbulence, mixing olfactory stimulants (see p. 118 for nervus olfactorius). The choanae (posterior nasal apertures) (**C**) are the posterior openings by which the cavitas nasi communicates with the pars nasalis pharyngis. Note the close proximity of the choanae to the tuba auditiva and tonsilla pharyngea in **A**.

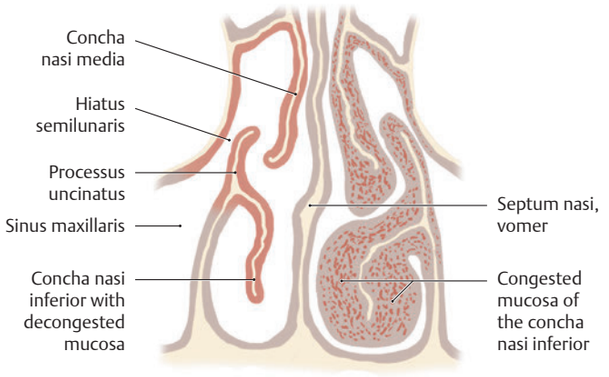


Fig. 7.19 **Functional states of the nasal mucosa**
Coronal section, anterior view. The function of the nasal mucosa is to warm and humidify the inspired air and mix olfactory stimulants. This is accomplished by an increase of blood flow through the mucosa, placing it in a congested (swollen) state. The mucous membranes are not simultaneously congested on both sides, but undergo a normal cycle of congestion and decongestion that lasts approximately six hours (the right side is decongested in the drawing). Examination of the cavitas nasi can be facilitated by first administering a decongestant to shrink the mucosa.

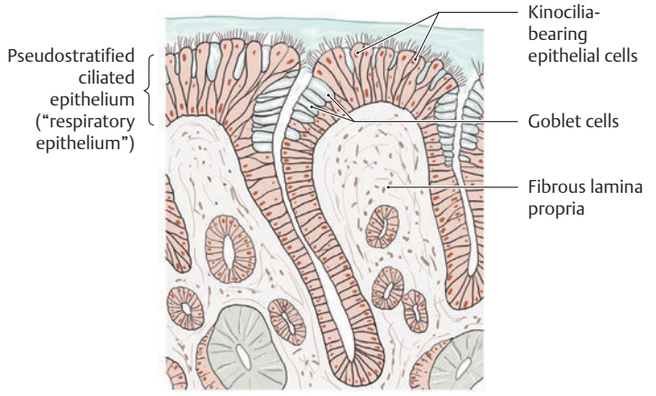
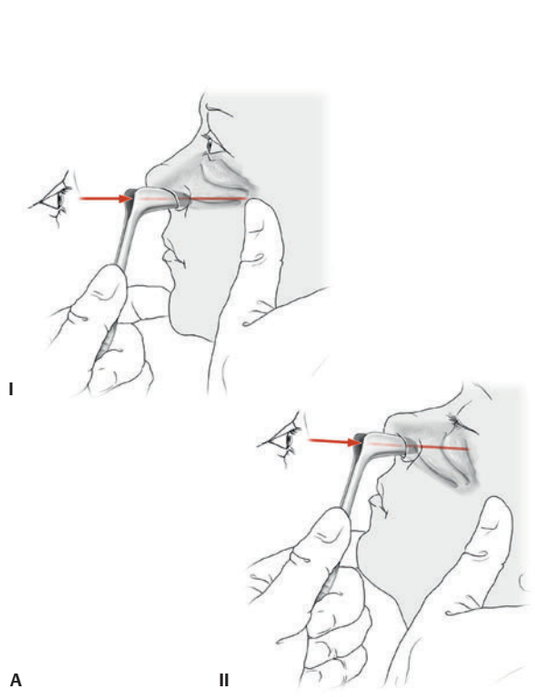


Fig. 7.20 **Histology of the nasal mucosa**
The surface of the pseudostratified respiratory epithelium of the nasal mucosa consists of kinocilia-bearing cells and goblet cells, which secrete their mucus into a watery film on the epithelial surface. Serous and seromucous glands are embedded in the connective tissue and also release secretions into the superficial fluid film. The directional fluid flow produced by the cilia is an important component of the nonspecific immune response. If coordinated beating of the cilia is impaired, the patient will suffer chronic recurring infections of the respiratory tract.



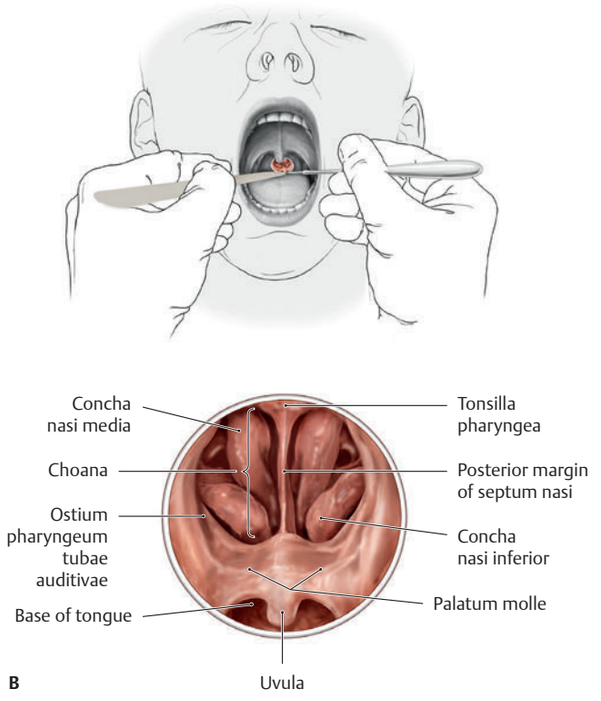


Fig. 7.21 **Anterior and posterior rhinoscopy**
A **Anterior rhinoscopy** is a procedure for inspection of the cavitas nasi. Two different positions (I, II) are used to ensure that all of the anterior cavitas nasi is examined.
B In **posterior rhinoscopy**, the choanae and tonsilla pharyngea are accessible to clinical examination. The rhinoscope can be angled and rotated to demonstrate the structures shown in the composite image. Today the rhinoscope is frequently replaced by an endoscope.

Nose & Sinus Paranasales: Histology & Clinical Anatomy

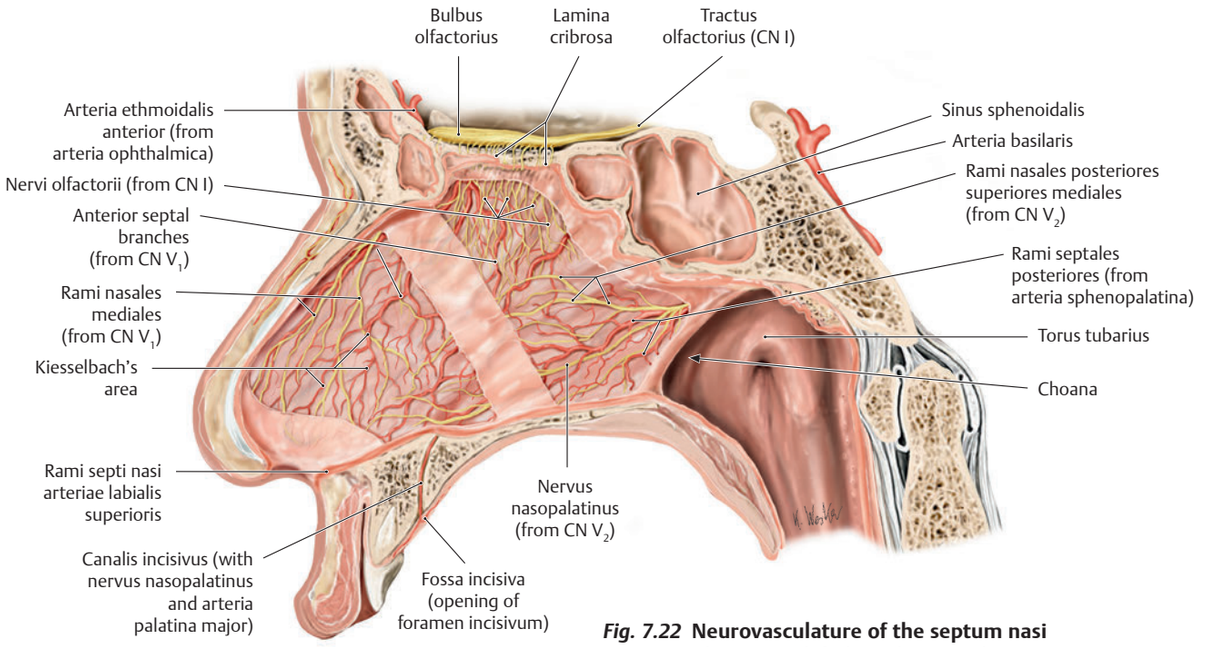


Fig. 7.22 **Neurovasculature of the septum nasi**
Parasagittal section, left lateral view. The septum nasi is supplied anterosuperiorly by CN V_1 and posteroinferiorly by CN V_2. It receives blood primarily from branches of the arteriae ophthalmica and maxillaris, with contribution from the arteria facialis (rami septi nasi of the arteria labialis superior).

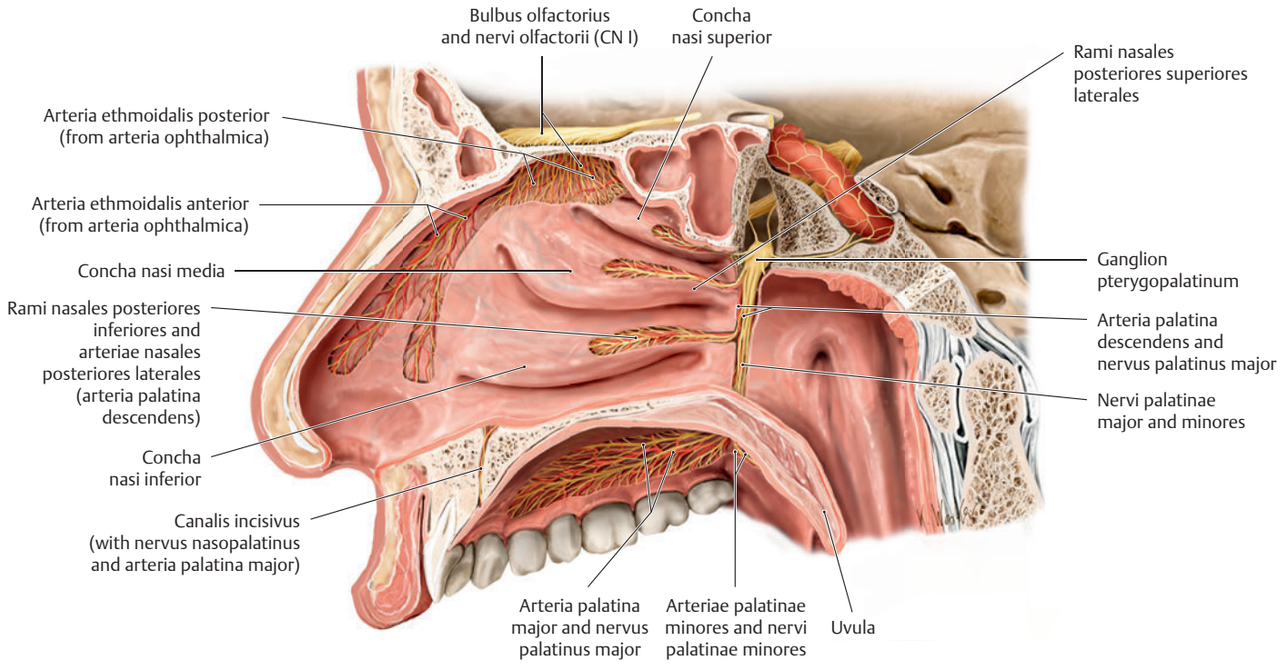


Fig. 7.23 **Neurovasculature of the lateral nasal wall**
Left medial view of right lateral nasal wall. The ganglion pterygopalatinum (located in the fossa pterygopalatina but exposed here) is an important relay in the parasympathetic nervous system. The CN V_2 nerve fibers pass through it to the small glandulae nasales of the conchae nasi, along with glandulae palatinae. The anterosuperior portion of the lateral nasal wall is supplied by branches of the arteria ophthalmica and CN V_1. *Note:* Nervi olfactorii (CN I) pass through thelamina cribrosa to the olfactory mucosa at the level of the concha nasi superior.

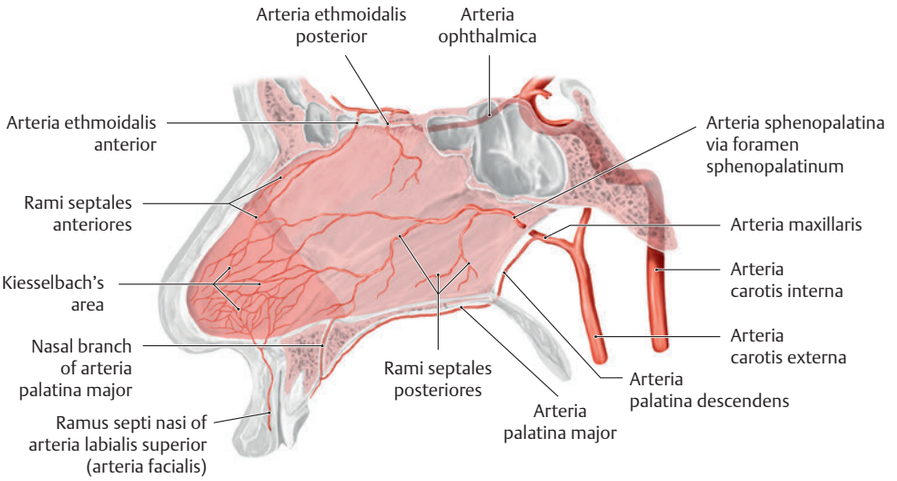


***Fig. 7.24* Arteries of the septum nasi**
Left lateral view of left side of septum. The vessels of the septum nasi arise from branches of the arteriae carotides externa and interna. The anterior part of the septum contains a highly vascularized area called Kiesselbach's area, which is supplied by vessels from both major arteries. This area is the most common site of significant nosebleed due to anastomoses.

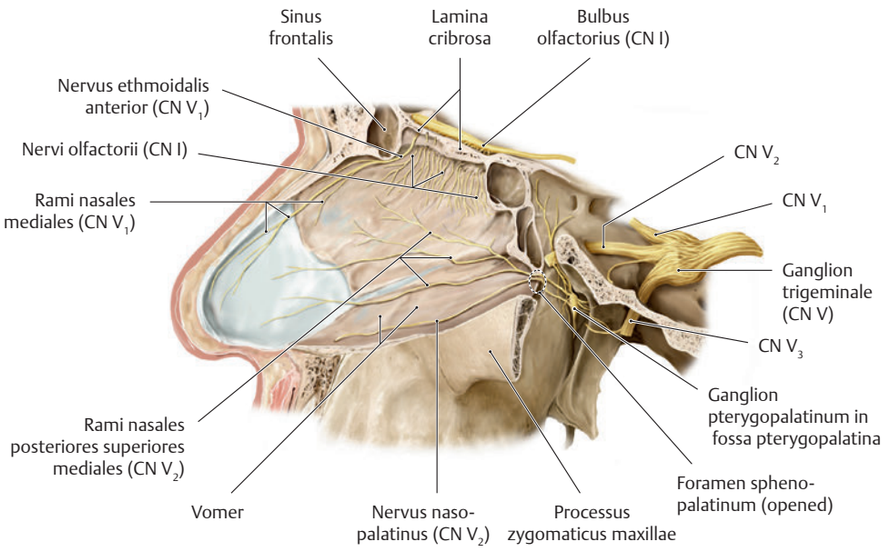


***Fig. 7.25* Nerves of the septum nasi**
Left lateral view of right lateral nasal wall. The septum nasi receives its general sensory innervation from branches of the nervus trigeminus (CN V). The anterosuperior part of the septum is supplied by branches of the nervus ophthalmicus division (CN V_1) and the rest by branches of the nervus maxillaris division (CN V_2). Bundles of olfactory nerve fibers (CN I) arise from receptors in the olfactory mucosa on the superior part of the septum, pass through the lamina cribrosa, and enter the bulbus olfactorius.(see p. 118 for discussion of nervus olfactorius [CN I]).

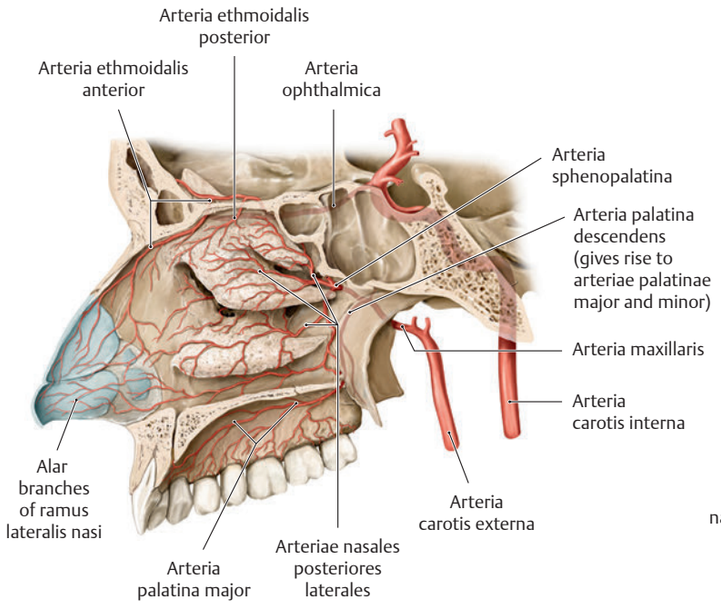


***Fig. 7.26* Arteries of the right lateral nasal wall**
Left lateral view of right lateral nasal wall. The nasal wall is supplied primarily by branches of the arteria ophthalmica (anterosuperiorly) and arteria maxillaris (posteroinferiorly), with contributions from the arteria facialis (alar branches of the ramus lateralis nasi).

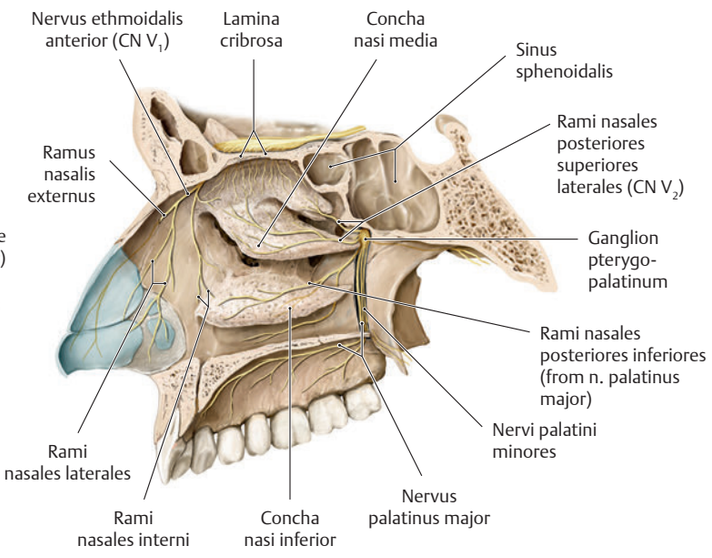


***Fig. 7.27* Nerves of the right lateral nasal wall**
Left lateral view of the right lateral nasal wall. The nasal wall derives its sensory innervation from branches of the nervus ophthalmicus division (CN V_1) and the nervus maxillaris division (CN V_2). Receptor neurons in the olfactory mucosa send their axons in the nervus olfactorius (CN I) to the bulbus olfactorius.

Olfactory System (Smell)

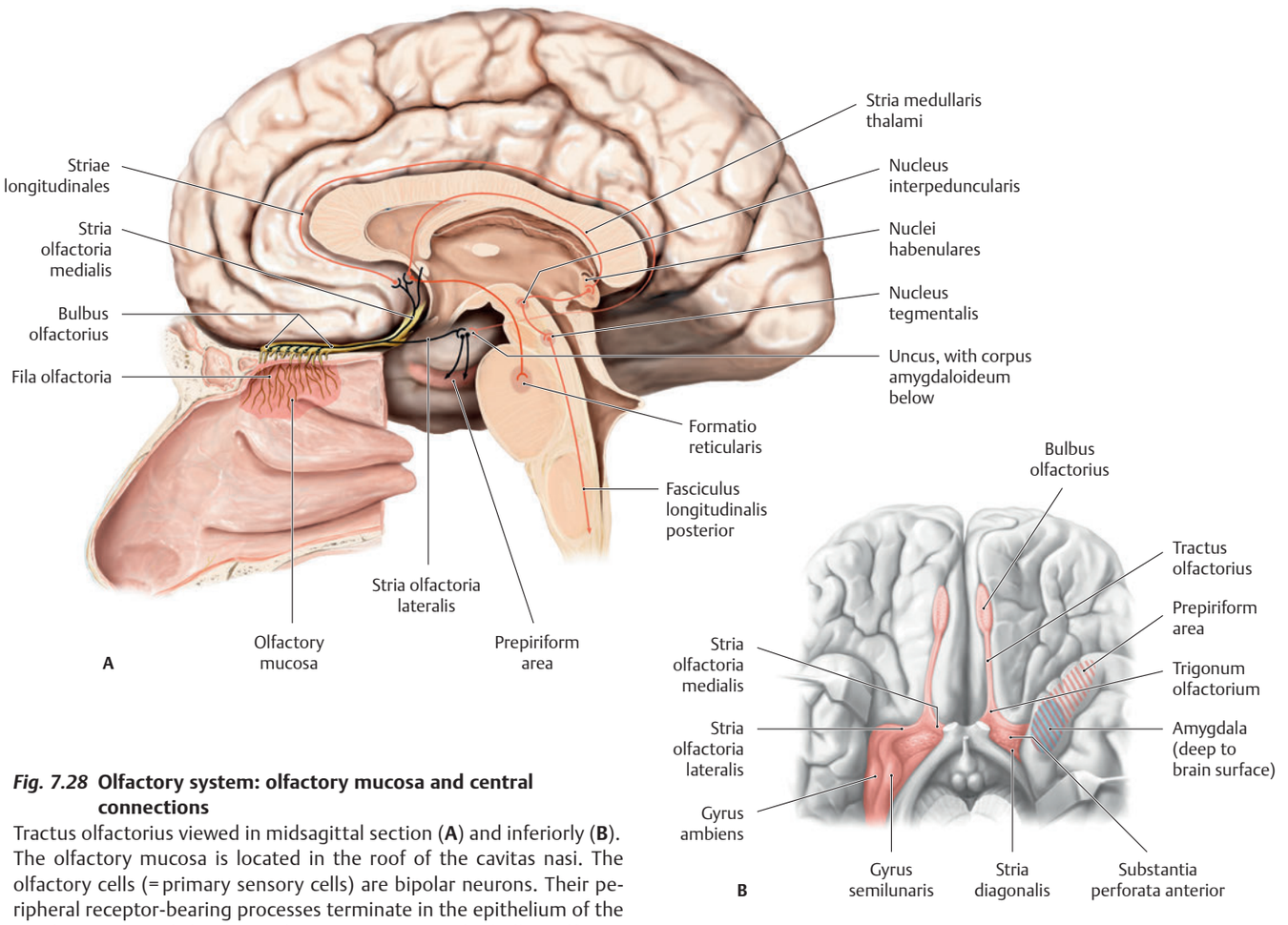


Fig. 7.28 **Olfactory system: olfactory mucosa and central connections**

Tractus olfactorius viewed in midsagittal section (**A**) and inferiorly (**B**). The olfactory mucosa is located in the roof of the cavitas nasi. The olfactory cells (= primary sensory cells) are bipolar neurons. Their peripheral receptor-bearing processes terminate in the epithelium of the nasal mucosa, and their central processes pass to the bulbus olfactorius. The bulbus olfactorius, where the second neurons of the olfactory pathway (mitral and tufted cells) are located, is considered an extension of the telencephalon. The axons of these second neurons pass centrally as the *tractus olfactorius.* In front of the substantia perforata anterior, the tractus olfactorius widens to form the trigonum olfactorium and splits into the striae olfactoriae lateralis and medialis.

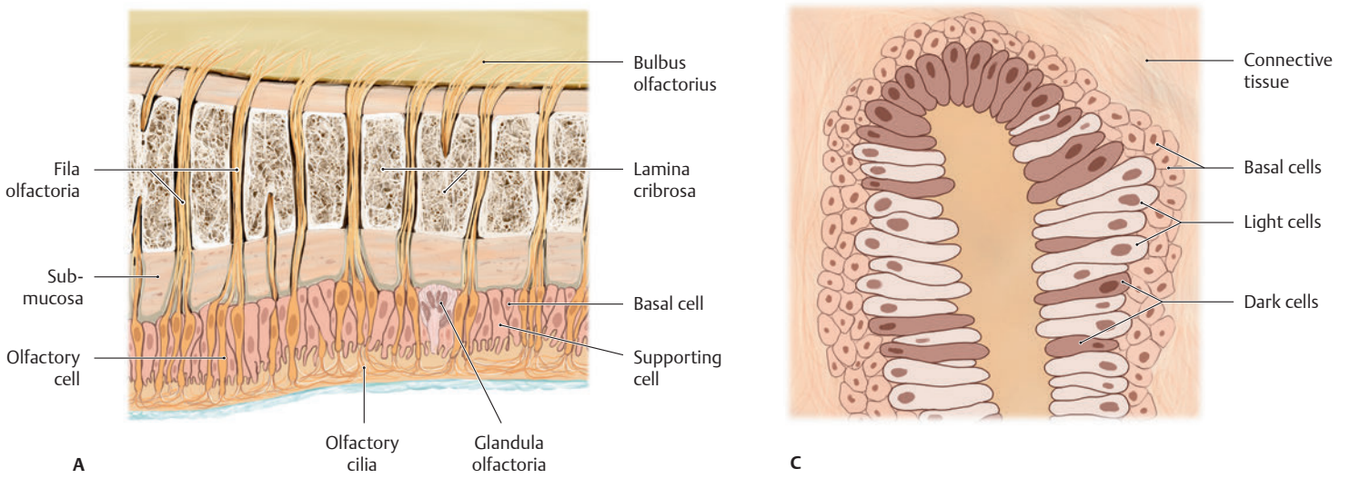
- Some of the axons of the tractus olfactorius run in the **stria olfactoria lateralis** to the olfactory centers: the amygdala, gyrus semilunaris, and gyrus ambiens. The prepiriform area (Brodmann area 28) is considered to be the primary olfactory cortex in the strict sense. It contains the third neurons of the olfactory pathway. *Note:* The prepiriform area is shaded in **B**, lying at the junction of the basal side of the lobus frontalis and the medial side of the lobus temporalis.
- Other axons of the tractus olfactorius run in the **stria olfactoria medialis** to nuclei in the area septalis (subcallosus), which is part of the limbic system, and to the tuberculum olfactorium, a small elevation in the substantia perforata anterior.
- Yet other axons of the tractus olfactorius terminate in the nucleus olfactorius anterior, where the fibers that cross to the opposite side branch off and are relayed. This nucleus is located in the trigonum olfactorium, which lies between the two striae olfactoriae and in front of the substantia perforata anterior.

Note: None of these three tracts are routed through the thalamus. Thus, the olfactory system is the only sensory system that is not relayed in the thalamus before reaching the cortex. There is, however, an indirect route from the primary olfactory cortex to the neocortex passing through the thalamus and terminating in the pars basalis telencephali. The olfactory signals are further analyzed in these basal portions of the forebrain (not shown).

The olfactory system is linked to other brain areas well beyond the primary olfactory cortical areas, with the result that olfactory stimuli can evoke complex emotional and behavioral responses. Noxious smells induce nausea, and appetizing smells evoke watering of the mouth. Presumably these sensations are processed by the hypothalamus, thalamus, and limbic system via connections established mainly by the fasciculus medialis telencephali and the striae medullares thalami. The fasciculus medialis telencephali distributes axons to the following structures:

- Nuclei hypothalami
- Formatio reticularis
- Nuclei salivatorii
- Nucleus posterior nervi vagi

The axons that run in the striae medullares thalami terminate in the nuclei habenulares. This tract also continues to the brainstem (truncus encephali), where it stimulates salivation in response to smell.



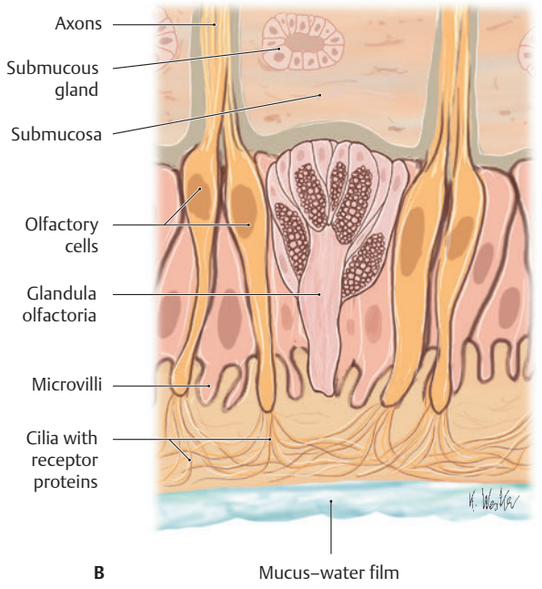


Fig. 7.29 **Olfactory mucosa and organum vomeronasale (Jacobson's organ) (VNO)**

The **olfactory mucosa** occupies an area of approximately 2 cm^2 on the roof of each cavitas nasi, and 10^7 primary sensory cells are concentrated in each of these areas (**A**). At the molecular level, the olfactory receptor proteins are located in the cilia of the sensory cells (**B**). Each sensory cell has only one specialized receptor protein that mediates signal transduction when an odorant molecule binds to it. Although humans are microsmatic, having a sense of smell that is feeble compared with other mammals, the olfactory receptor proteins still make up 2 % of the human genome. This underscores the importance of olfaction in humans. The primary olfactory sensory cells have a life span of approximately 60 days and regenerate from the basal cells (life-long division of neurons). The bundled central processes (axons) from hundreds of olfactory cells form fila olfactoria (**A**) that pass through the lamina cribrosa of the os ethmoidale and terminate in the *bulbus olfactorius*, which lies above the lamina cribrosa. The VNO (**C**) is located on both sides of the anterior septum nasi. It is an accessory olfactory organ and is generally considered vestigial in adult humans. However, it responds to steroids and evokes subconscious reactions in subjects (possibly influences the choice of a mate). Mate selection in many animal species is known to be mediated by olfactory impulses that are perceived in the VNO.

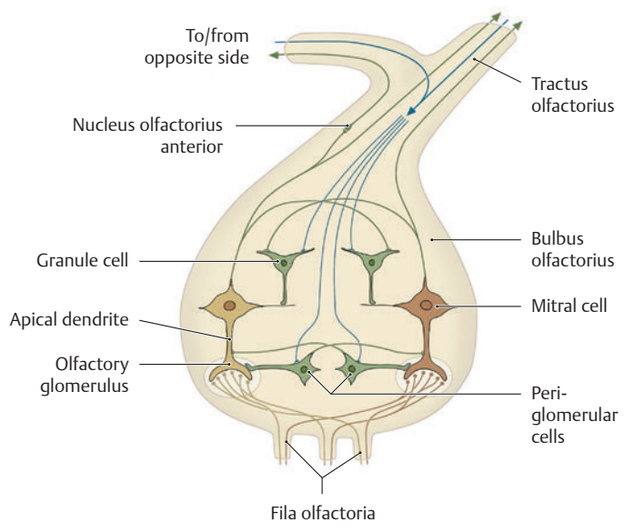


Fig. 7.30 **Synaptic patterns in the bulbus olfactorius**

Specialized neurons in the bulbus olfactorius, called mitral cells, form apical dendrites that receive synaptic contact from the axons of thousands of primary sensory cells. The dendrite plus the synapses make up the *olfactory glomeruli.* Axons from sensory cells with the same receptor protein form glomeruli with only one or a small number of mitral cells. The basal axons of the mitral cells form the tractus olfactorius. The axons that run in the tractus olfactorius project primarily to the olfactory cortex but are also distributed to other nuclei in the central nervous system. The axon collaterals of the mitral cells pass to granule cells: both granule cells and periglomerular cells inhibit the activity of the mitral cells, causing less sensory information to reach higher centers. These inhibitory processes are believed to heighten olfactory contrast, which aids in the more accurate perception of smells. The tufted cells, which also project to the primary olfactory cortex, are not shown.

Cavitas Oris: Overview

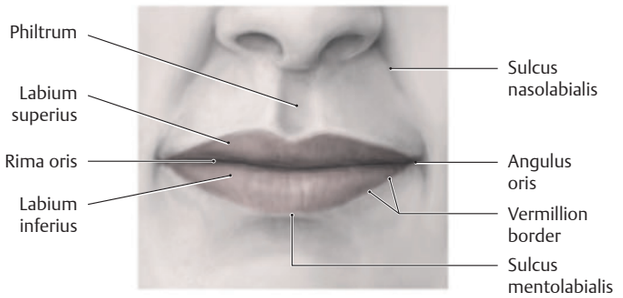
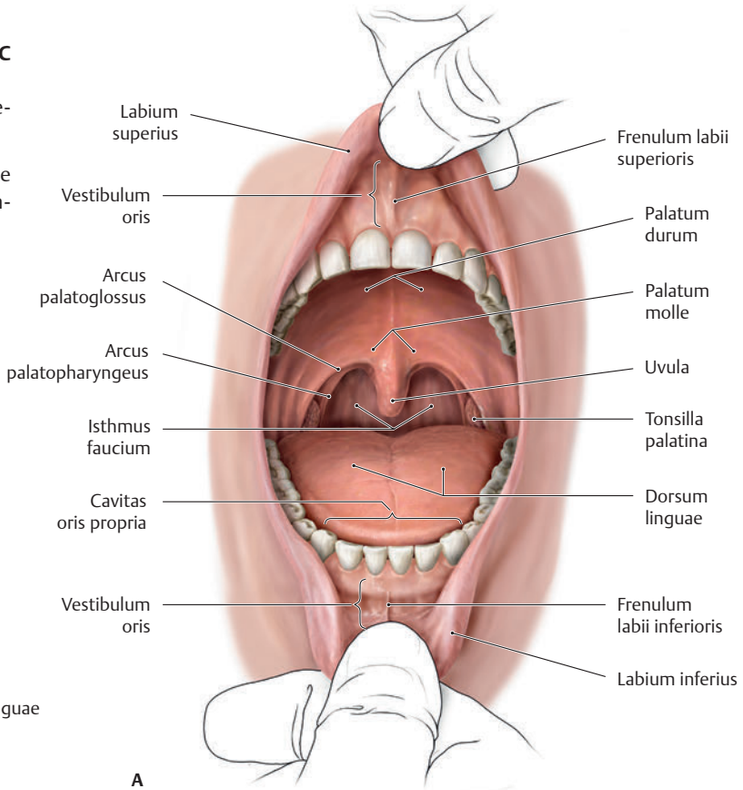
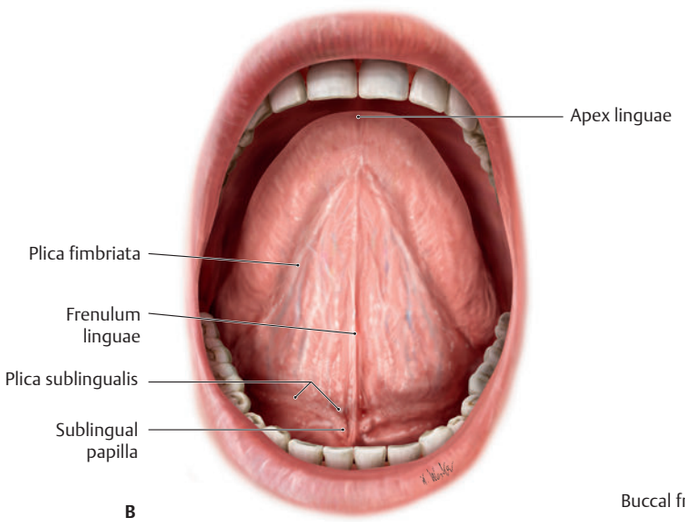


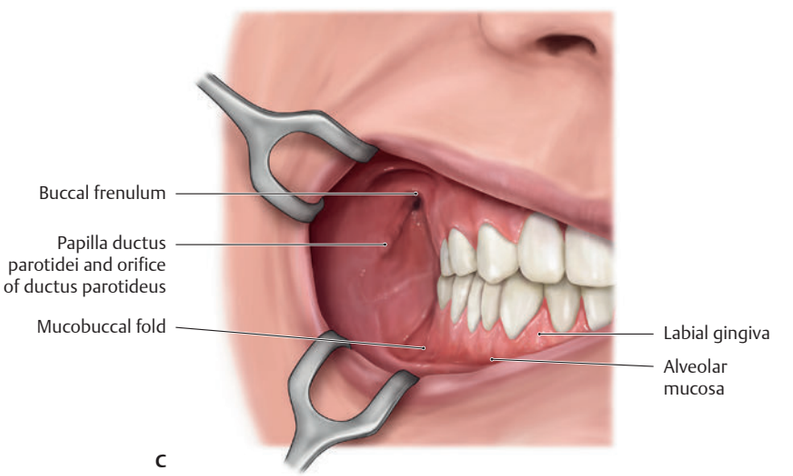
Fig. 8.1 **Lips and labial creases**
Anterior view. The labia superius and inferius meet at the angle of the mouth. The rima oris opens into the cavitas oris. Changes in the lips noted on visual inspection may yield important diagnostic clues: Blue lips (cyanosis) suggest a disease of the heart, lung, or both, and deep nasolabial creases may reflect chronic diseases of the digestive tract.

Fig. 8.2 **Cavitas oris**
A Anterior view. **B** Anterior view showing ventral surface of tongue. **C** Left lateral view.
The arci dentales (with the processus alveolaris maxillae and pars alveolaris mandibulae) subdivide the cavitas oris into two parts:

- **Vestibulum oris:** portion outside the arci dentales, bounded on one side by the lips and cheeks and on the other side by the arci dentales.
- **Cavitas oris propria:** region within the arci dentales.







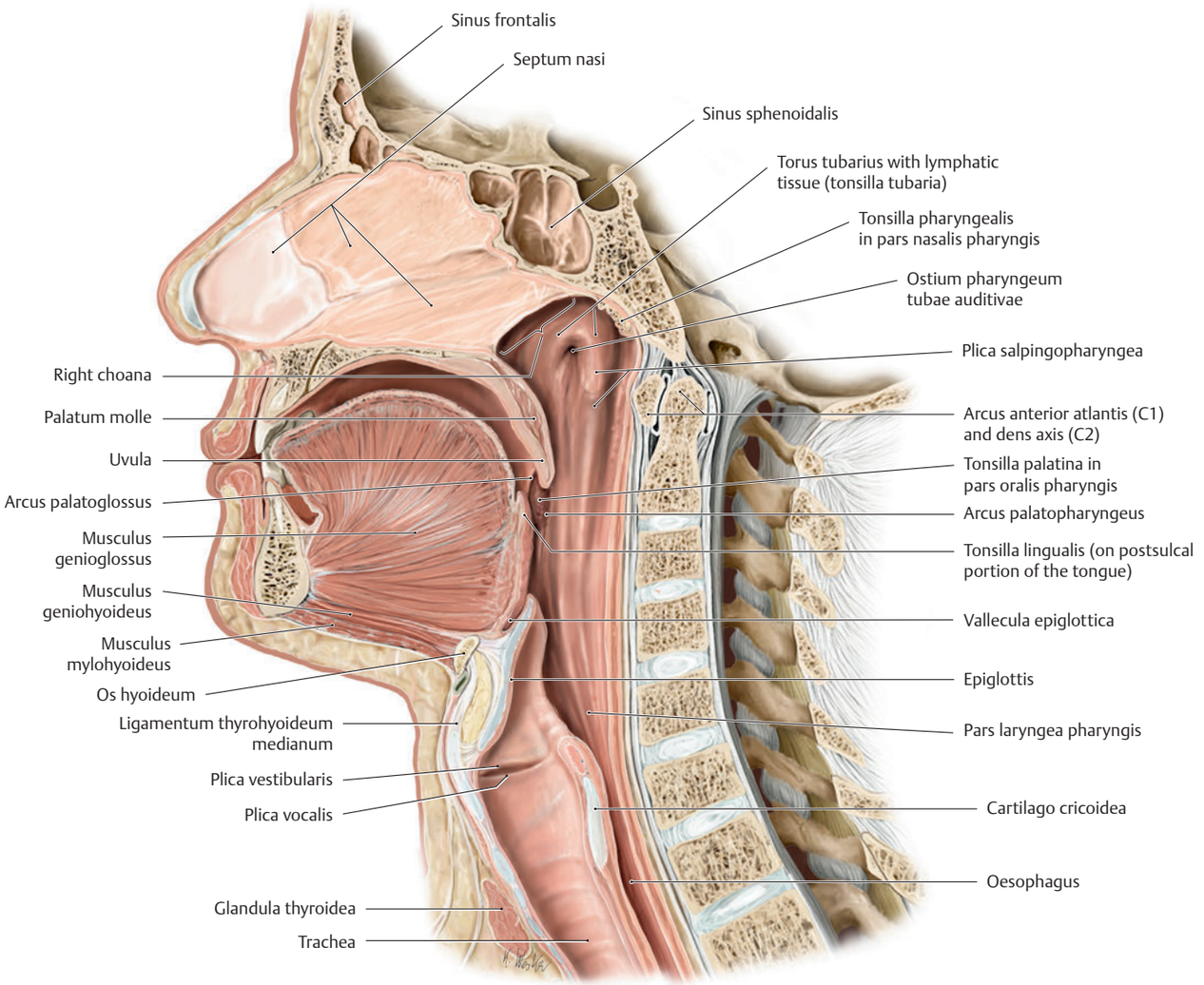
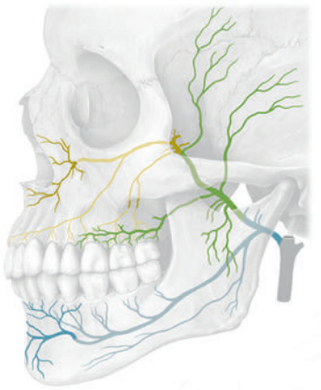


Fig. 8.3 **Topography of the cavitas oris and pharynx**
Midsagittal section, left lateral view. The cavitas oris is located inferior to the cavitas nasi and anterior to the pharynx. The roof of the cavitas oris is formed by the palatum durum in its anterior two thirds and by the palatum molle (velum) in its posterior one third. Its inferior boundary is formed by the musculus mylohyoideus. Laterally, the cavitas oris is bounded by the cheeks; posteriorly, it is continuous with the pars oralis pharyngis.

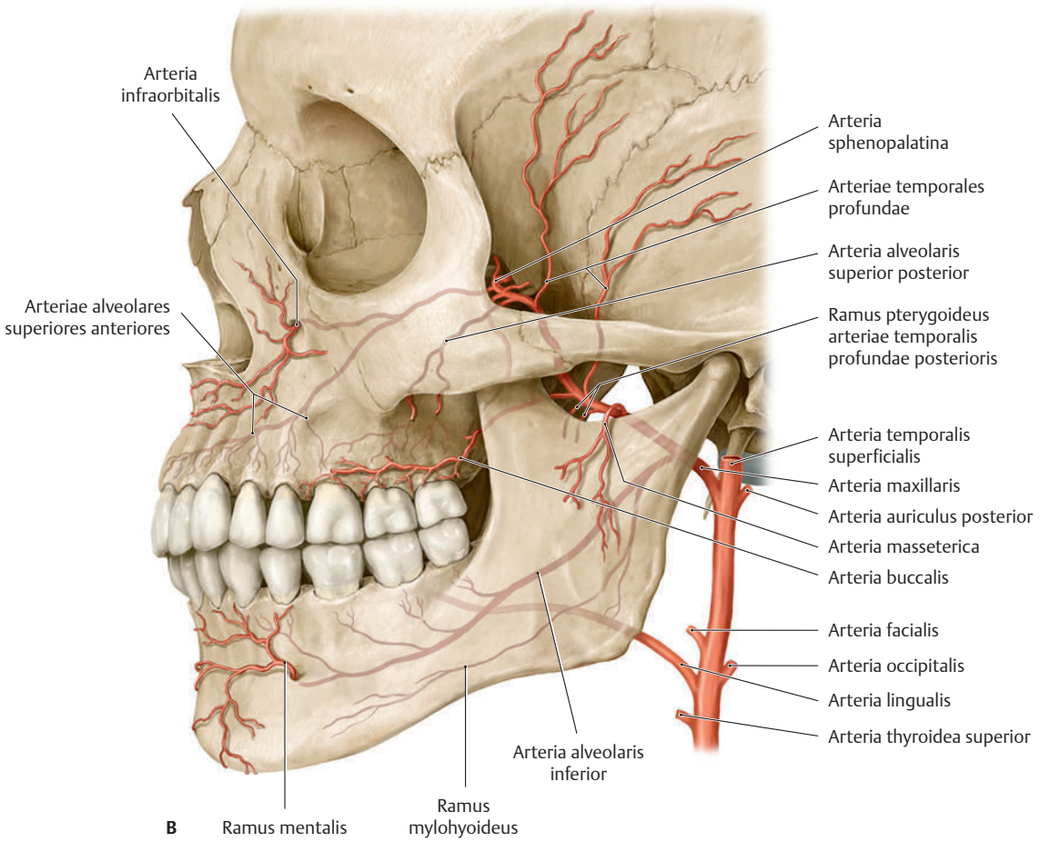
Fig. 8.4 **Oral cancer**
A Cancerous lesion of the oral floor. **B** Cancerous lesion of the tongue. Most oral cancers are squamous cell carcinomas and can be attributed to the use of alcohol and tobacco (synergistic effect). They typically occur on the oral floor or the ventral (inferior) or lateral surface of the tongue and present as a painless ulcer which is firm with raised edges and an indurated, inflamed base. Other presentations include an area of leukoplakia (a white patch), erythroplakia (red patch), or a combination of the two. Lesions that occur on the oral floor tend to undergo malignant transformation more readily than those in other locations in the cavitas oris. Pain from oral cancer occurs later in the pathogenesis and is usually due to superinfection.

Vasculature of the Cavitas Oris



A

Fig. 8.5 **Arteria maxillaris**
Left lateral view. **A** Schematic. **B** Course of the arteria maxillaris.
A The arteria maxillaris can be divided into three parts: mandibular (blue); pterygoid (green), and pterygopalatine (yellow).
B The arteria maxillaris is the principal artery supplying the cavitas oris. The mandibular part supplies the mandibular teeth, gingiva, and mucosa, and contributes to the supply of certain muscles of mastication and of the palatum molle. The pterygoid part supplies the muscles of mastication and the buccal mucosa. The pterygopalatine part supplies the maxillary teeth, gingiva, mucosa, palatum durum, and palatum molle, and contributes to the supply of the labium superius.
Note: This represents only those parts of the arteria maxillaris that contribute to the blood supply of the structures of the cavitas oris. For full details of the structures that the arteria maxillaris supplies, see **Table 3.6,** p. 57.
Other arteries that contribute to the blood supply of the cavitas oris include the arteria lingualis(p. 52), which supplies the tongue and oral floor, and the arteria facialis (p. 53), which supplies the labium inferius (arteria labialis inferior) and labium superius (arteria labialis superior).



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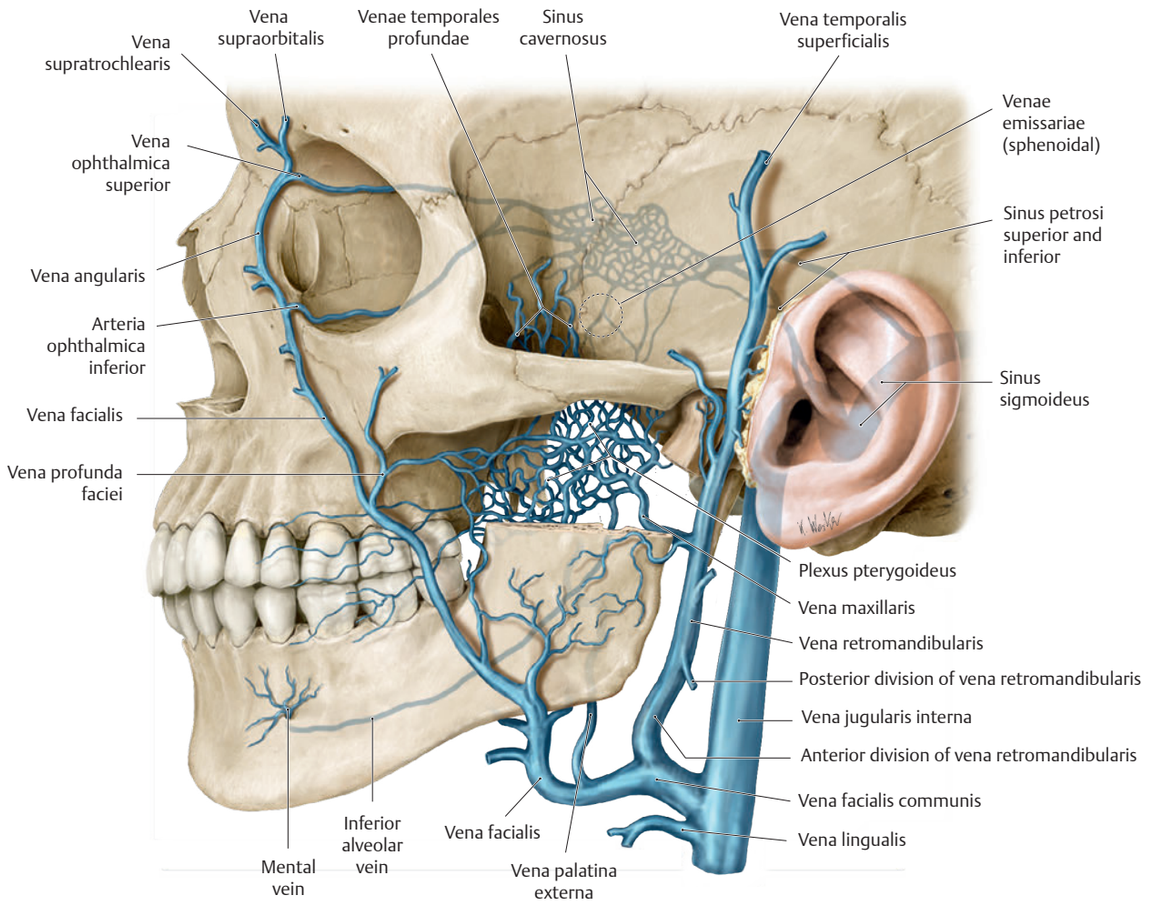


Fig. 8.6 **Venous drainage of the cavitas oris**
Left lateral view. Veins within the mandibular teeth, gingiva, and mucosa combine to form inferior alveolar veins, which drain to the plexus pterygoideus. Likewise, veins within the maxillary teeth, gingiva, and mucosa form the superior alveolar veins, which drain to the Plexus pterygoideus. Veins from the palata durum and molle also drain to the plexus pterygoideus . Middle and anterior superior alveolar veins drain into the infraorbital vein which drains into the plexus pterygoideus of veins. The Vena lingualis drains the tongue and oral floor. The vena facialis contributes to the venous drainage of the mandibular teeth.

Innervation of the Cavitas Oris

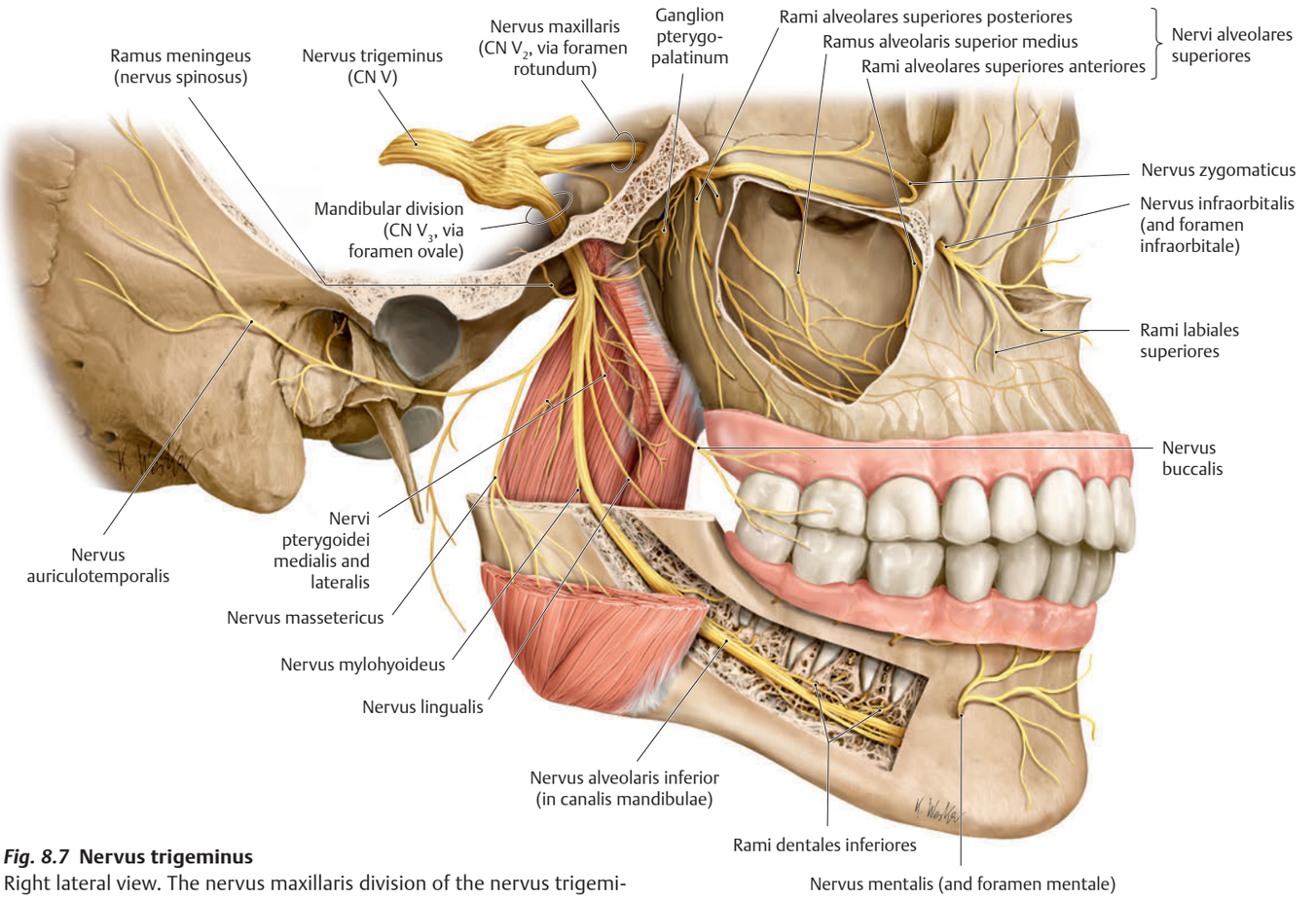


Fig. 8.7 **Nervus trigeminus**
Right lateral view. The nervus maxillaris division of the nervus trigeminus (CN V_2) and the nervus mandibularis division of the nervus trigeminus (CN V_3) innervate the structures of the cavitas oris via their many branches. For full details see pp. 126–129.

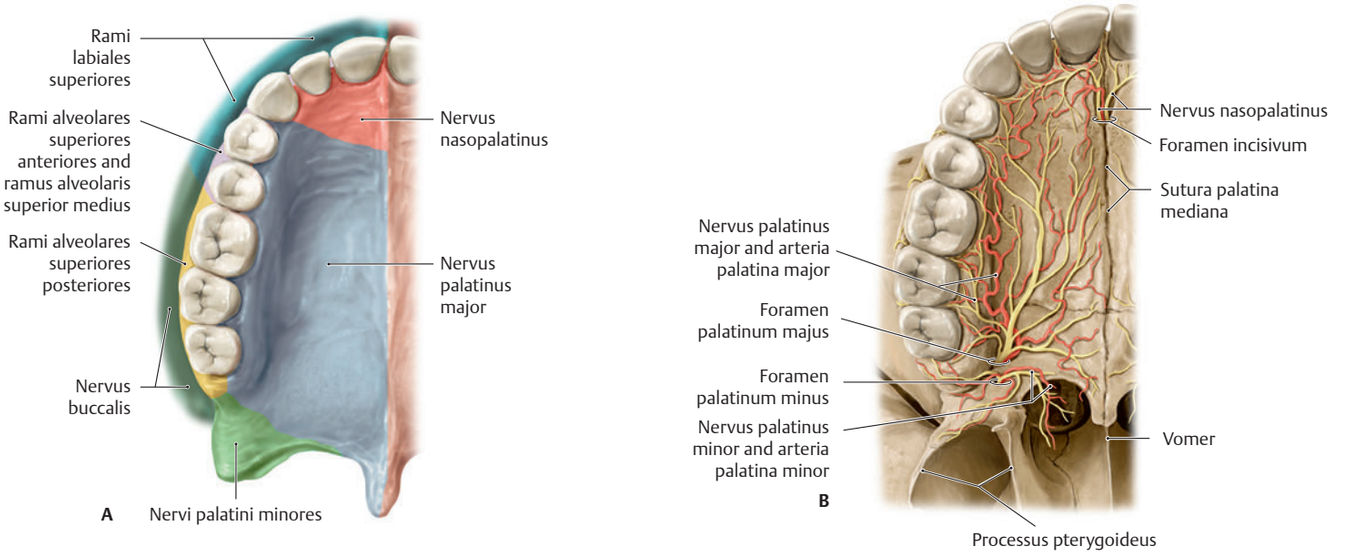
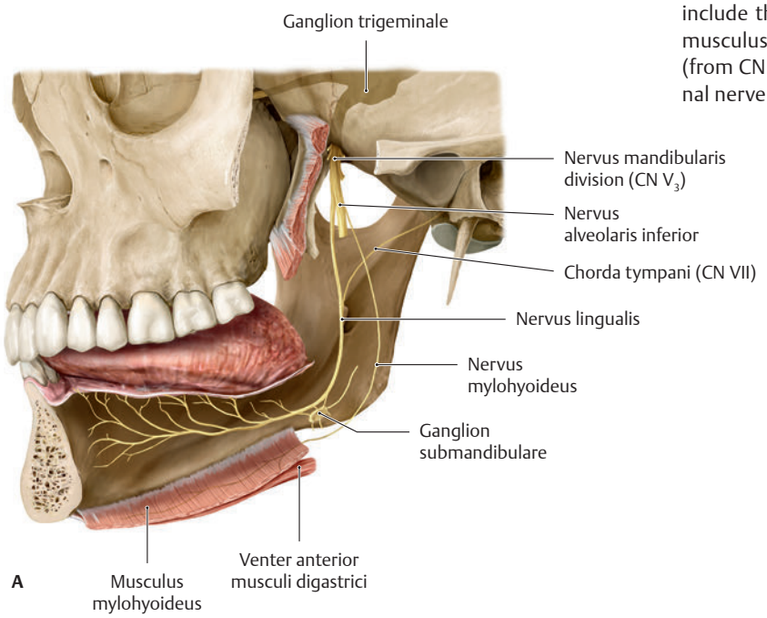
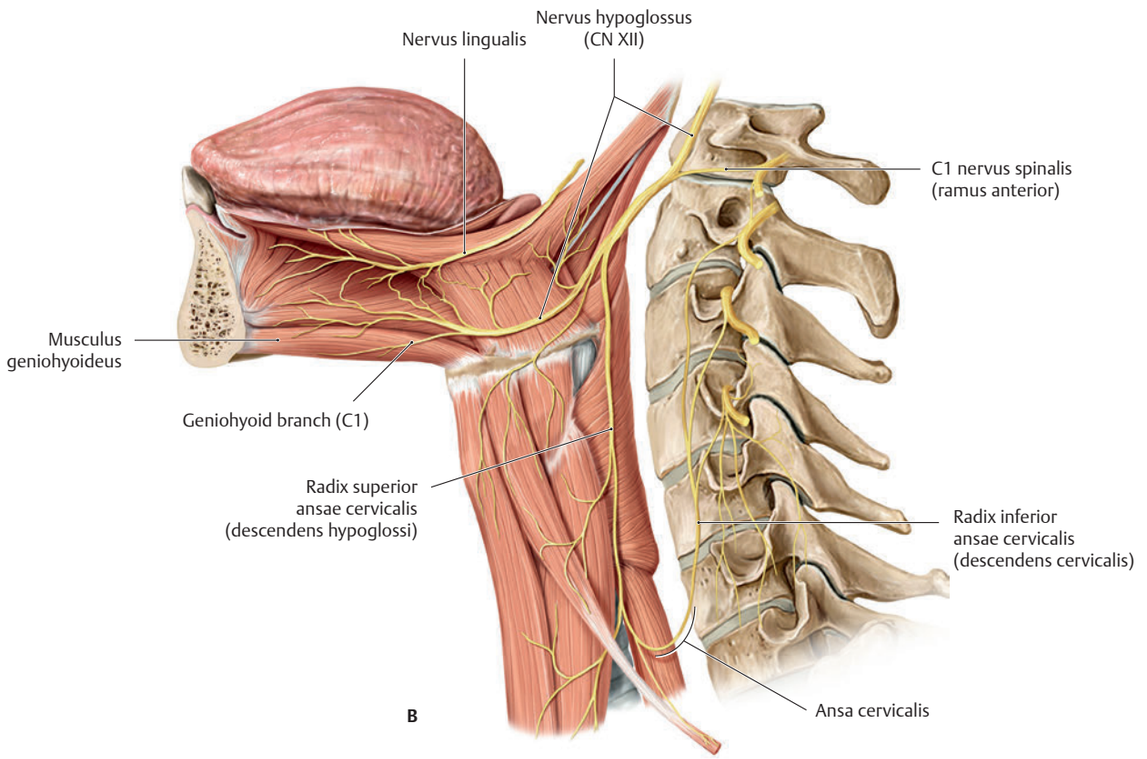


Fig. 8.8 **Neurovasculature of the palatum durum**
Inferior view. **A** The palatum durum receives sensory innervation primarily from the terminal branches of the nervus maxillaris division of the nervus trigeminus (CN V_2). *Note:* The nervus buccalis is a branch of the nervus mandibularis division of the nervus trigeminus (CN V_3). **B** The arteries of the palatum durum arise from the arteria maxillaris (a branch of the arteria carotis externa)

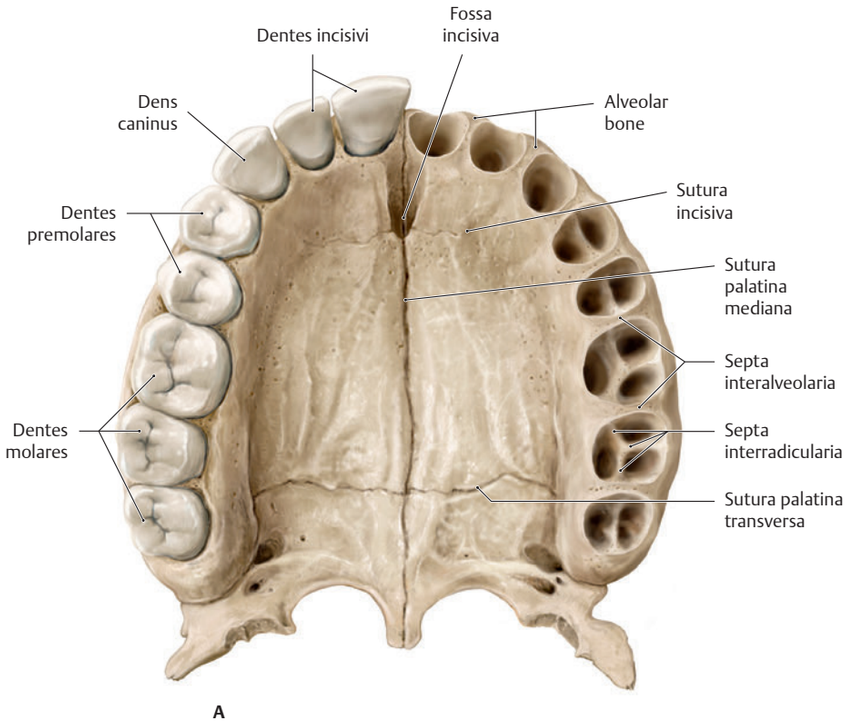
Fig. 8.9 **Innervation of the muscles of the oral floor**
A Left lateral view with left half of the mandibula removed. **B** Left lateral view of the muscles of the oral floor. The muscles of the oral floor include the musculus mylohyoideus and musculus geniohyoides. The musculus mylohyoideus is innervated by the nervus mylohyoideus (from CN V_3); the musculus geniohyoideus is innervated by the C1 spinal nerve via the nervus hypoglossus (CN XII).





Teeth in situ & Terminology

Humans have two successive sets of teeth: deciduous teeth (dentes decidui) and their permanent replacements. There are four different forms of teeth: incisor (dens incisivus), canine (dens caninus), premolar (dens premolaris; not present in the deciduous dentition), and molar (dens molaris). Teeth are set in sockets (alveoli) composed of alveolar bone and held in place by the elastic connective tissue.



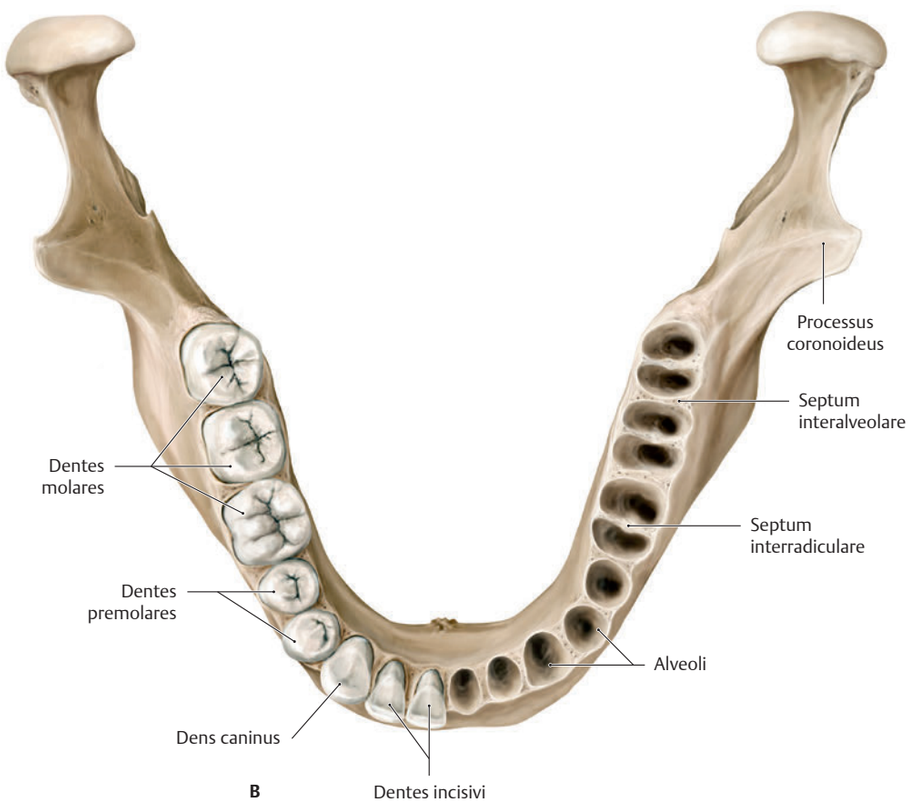


Fig. 8.10 **Dentes permanentes in adults**
A Inferior view of the maxilla (with teeth removed on left side).
B Superior view of the mandibula (with teeth removed on left side).
The 16 teeth in both the maxilla and the mandibula in humans are aligned in a bilateral, symmetrical fashion to suit their different chewing functions. The teeth in each half of the maxilla and mandibula consist of: two dentes incisivi, one dens caninus, two dentes premolares, and three dentes molares. The dentes incisivi and caninus are responsible for ripping the food while the dentes molares are responsible for grinding it.
The teeth have been removed on right side of each image to reveal the alveoli, which hold the teeth. In the anterior area (where the dentes incisivi and canini are located), the labial plate of compact bone is extremely thin (approximately 0.1 mm) and the roots of these teeth are palpable. The septa interalveolaria separate the alveoli of two adjacent teeth. The septa interradicularia separate the roots of teeth with multiple roots.
Alveolar ostitis (dry socket), an inflammation of the alveolar bone, may occur following tooth extraction when the blood clot that would normally occupy the socket does not form properly (e.g., due to smoking) or is displaced (e.g., by mouth rinsing), exposing the underlying bone and nerves and allowing an infection to flourish.

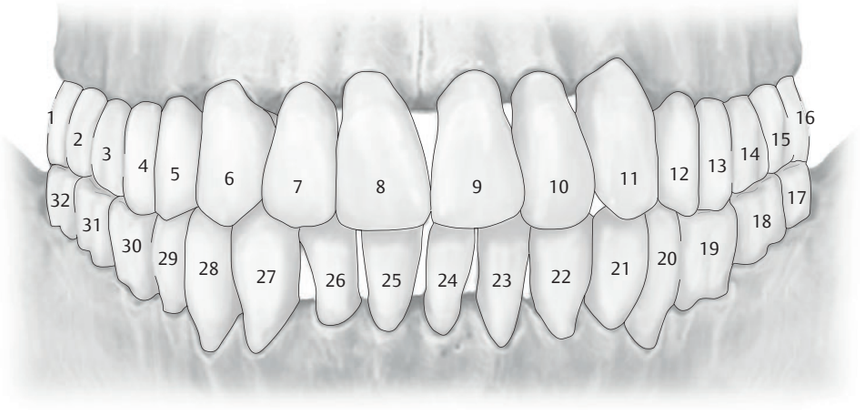


Fig. 8.11 **Coding the dentes permanentes**
In the United States, the dentes permanentes are numbered sequentially, not assigned to quadrants. Progressing in a clockwise fashion (from the perspective of the dentist), the teeth of the arcus dentalis maxillaris are numbered 1 to 16, and those of the arcus dentalis mandibularis are considered 17 to 32. *Note:* The third upper dens molaris (dens serotinus, wisdom tooth) on the patient's right is considered 1.

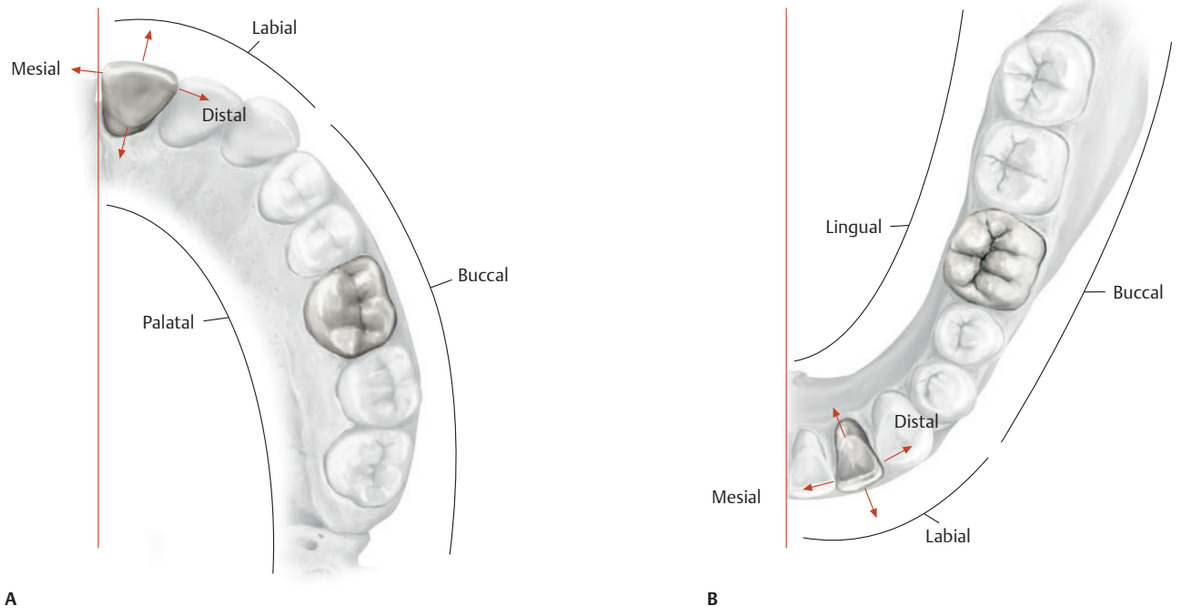


Fig. 8.12 **Designation of tooth surfaces**
A Inferior view of the arcus dentalis maxillaris. **B** Superior view of the arcus dentalis mandibularis. **C** Buccal, distal, and occlusal views of the right mandibular first dens molaris (tooth 30). The *mesial* and *distal* tooth surfaces are those closest to and farthest from the midline, respectively. The term *labial* is used for dentes incisivi and canini, and *buccal* is used for dentes premolares and molares. *Palatal* denotes the inside surface of maxillary teeth, and *lingual* denotes the inside surface of mandibular teeth. **C** shows the coronal, apical, and cervical directions of a tooth and the approximal surfaces, which *contact*, or *face*, the adjacent teeth. These designations are used to describe the precise location of small carious lesions.

Structure of the Teeth & Periodontium

The periodontium includes all the structures that bind the tooth to its bony socket:

- gingiva,
- cementum,
- periodontal ligament, and
- alveolar bone.

Its essential functions include:

- anchoring the teeth in alveolar bone and transforming chewing pressure into tensile stress,
- mediating the sensation of pain and regulating chewing pressure through nerve fibers and sensitive nerve endings,
- defending against infection through efficient separation of the cavitas oris and the dental root region and by having a large number of defense cells, and
- rapid metabolism and high regenerative capacity, via its rich blood supply

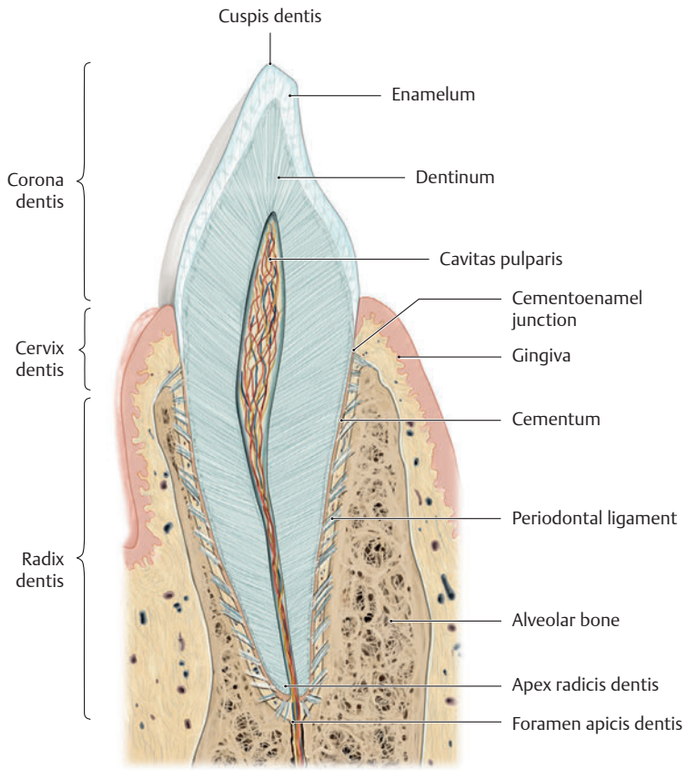


Fig. 8.13 **Parts of the tooth**
Cross-section of a tooth (mandibular incisor). The teeth consist of an enamelum-covered corona dentis that meets the cementum-covered radices at the cervix (cementoenamel junction). The body of the tooth is primarily dentinum.

Table 8.1 **Structures of the tooth**

Protective coverings: These hard, avascular layers of tissue protect the underlying body of the tooth. They meet at the cervical margin (cervix dentis, cementoenamel junction). Failure to do so exposes the underlying dentinum, which has extremely sensitive pain responses.	**Enamelum:** Hard, translucent covering of the corona dentis of the tooth. Maximum thickness (2.5 mm) occurs over the cusps. Enamelum prisms lie parallel to each other and are composed of hydroxyapatite [$Ca_5(PO_4)_3(OH)$].The enamelum covering meets the cementum at the neck (cervical margin, cementoenamel junction).
	Cementum: Bonelike covering of the radices dentis, lacking neurovascular structures.
Body of the tooth: The tooth is primarily composed of dentinum, which is supported by the vascularized pulpa dentis.	**Dentinum:** Tough tissue composing the majority of the body of the tooth. It consists of extensive networks of S-shaped tubules (intratubular dentinum) surrounded by peritubular dentinum. The tubules connect the underlying pulpa dentis to the overlying tissue. Exposed dentinum is extremely sensitive due to extensive innervation via the pulpa dentis.
	Pulpa dentis: Located in the cavitas pulpalis and canales radicis dentis, the pulpa dentis is a well-vascularized layer of textus connectivus laxus. Neurovascular structures enter the foramen apicis dentis at the apex radicis dentis. The pulpa dentis receives sympathetic innervation from the ganglion cervicale superius and sensory innervation from the ganglion trigeminale (CN V).
Periodontium: The tooth is anchored and supported by the periodontium, which consists of several tissue types. *Note:* The cementum is also considered part of the periodontium.	**Periodontal ligament:** Dense connective tissue fibers that connect the cementum of the roots in the osseous socket to the alveolar bone.
	Alveolar bone (processus alveolaris maxillae and pars alveolaris mandibulae)**:** The portion of the maxilla or mandibula in which the radices dentium is embedded are considered the processus alveolaris or pars alveolaris (the more proximal portion of the bone is considered the corpus).
	Gingiva: The attached gingivae bind the alveolar periosteum to the teeth; the free gingiva composes the 1 mm tissue radius surrounding the neck of the tooth. A mucogingival line marks the boundary between the keratinized gingivae of the arcus dentalis mandibularis and the nonkeratinized lingual mucosa. The palatal mucosa is masticatory (orthokeratinized), so no visual distinction can be made with the gingiva of the arcus dentalis maxillaris. Third molars (dentes serotini) often erupt through the mucosogingival line. The oral mucosa cannot support the tooth, and food can become trapped in the regions lacking attached gingiva.

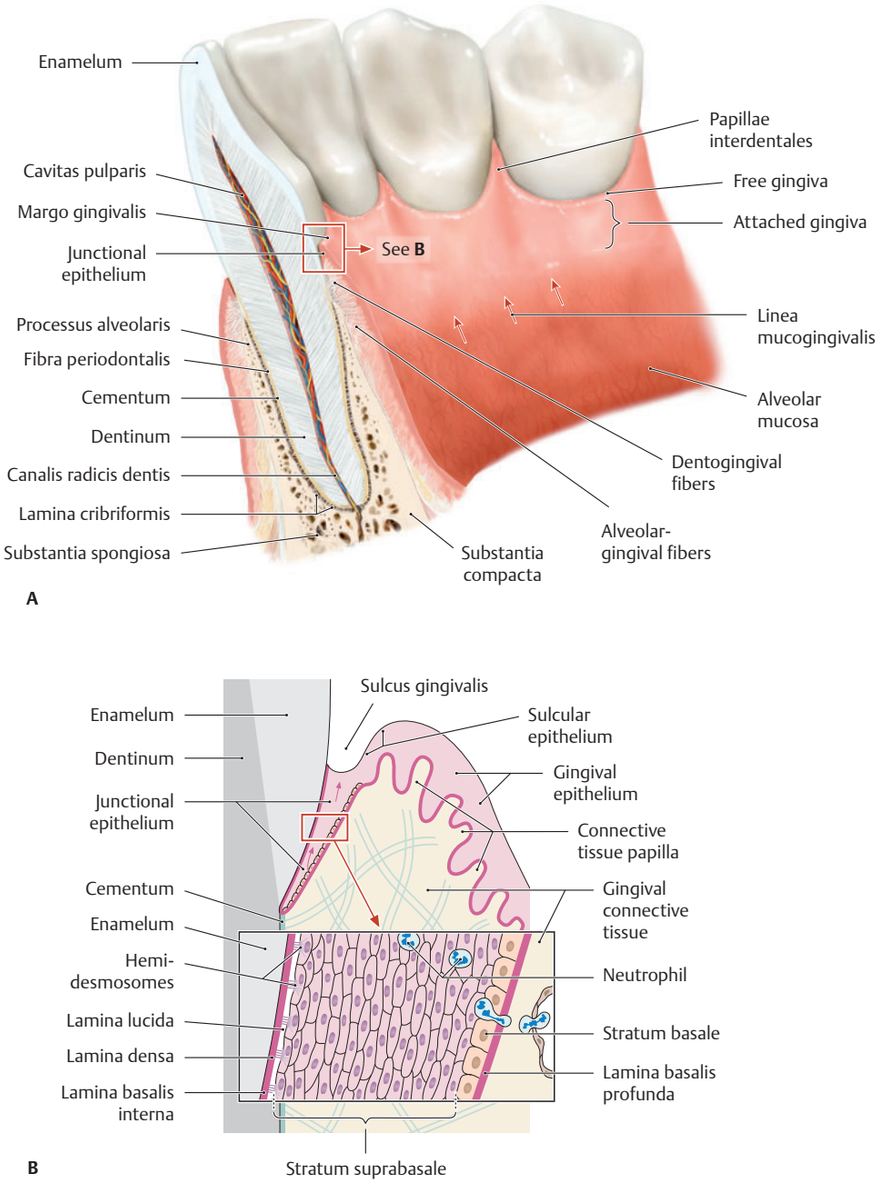


Fig. 8.14 **Gingiva**
A Gingiva. **B** Junctional epithelium.
A The gingiva extends from the margo gingivalis to the mucogingival border. There, the gingival epithelium blends into the considerably more reddish alveolar epithelium.
There is a clinical distinction between two types of gingiva:

- **Free gingiva** surrounds the neck of the tooth like a cuff and is attached only to the cervical enamelum. The sulcus gingivalis is a channel that runs around the tooth between the free gingiva and the junctional epithelium.
- **Attached gingiva** extends from the sulcus gingivalis to the mucogingival border. It is tightly bound to both the cementum at the neck of the tooth and the processus alveolaris by dentogingival fibers.

B The junctional epithelium attaches to the surface of the cementum by hemidesmosomes and lamina basalis, thereby ensuring a complete attachment of the oral mucosa to the tooth surface. The junctional epithelium becomes broader in the apical-coronal direction.
Note: The integrity of the junctional epithelium is a precondition for the health of the entire periodontium. If bacterial colonization from dental plaque leads to inflammation of the cervix dentis, the junctional epithelium detaches from the tooth and so-called "gingival pockets" form in the area around the sulcus gingivalis. This is called *periodontitis*.

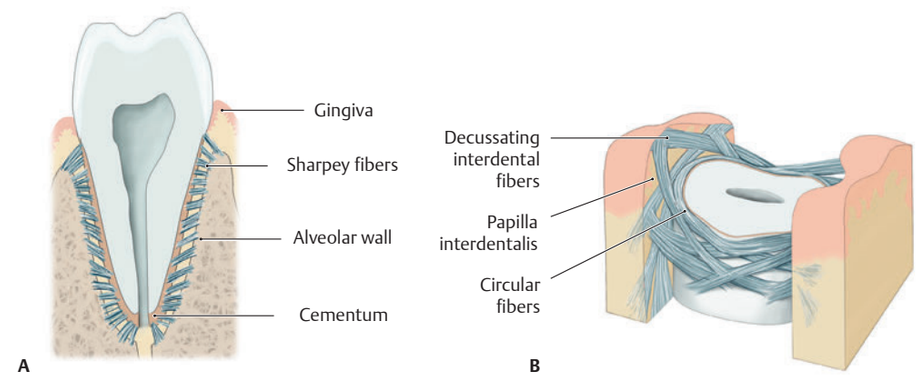


Fig. 8.15 **Periodontal ligament**
A The Sharpey fibers of the periodontal ligament pass obliquely downward from the alveolar bone and insert into the cementum of the tooth. This arrangement transforms masticatory pressures on the dental arch into tensile stresses acting on the fibers and anchored bone (pressure would otherwise lead to alveolar bone atrophy).
B Many of the tough collagenous fiber bundles in the connective tissue core of the gingiva above the alveolar bone are arranged in a screwlike pattern around the tooth further strengthening its attachment.

Maxillary Dentes Permanentes

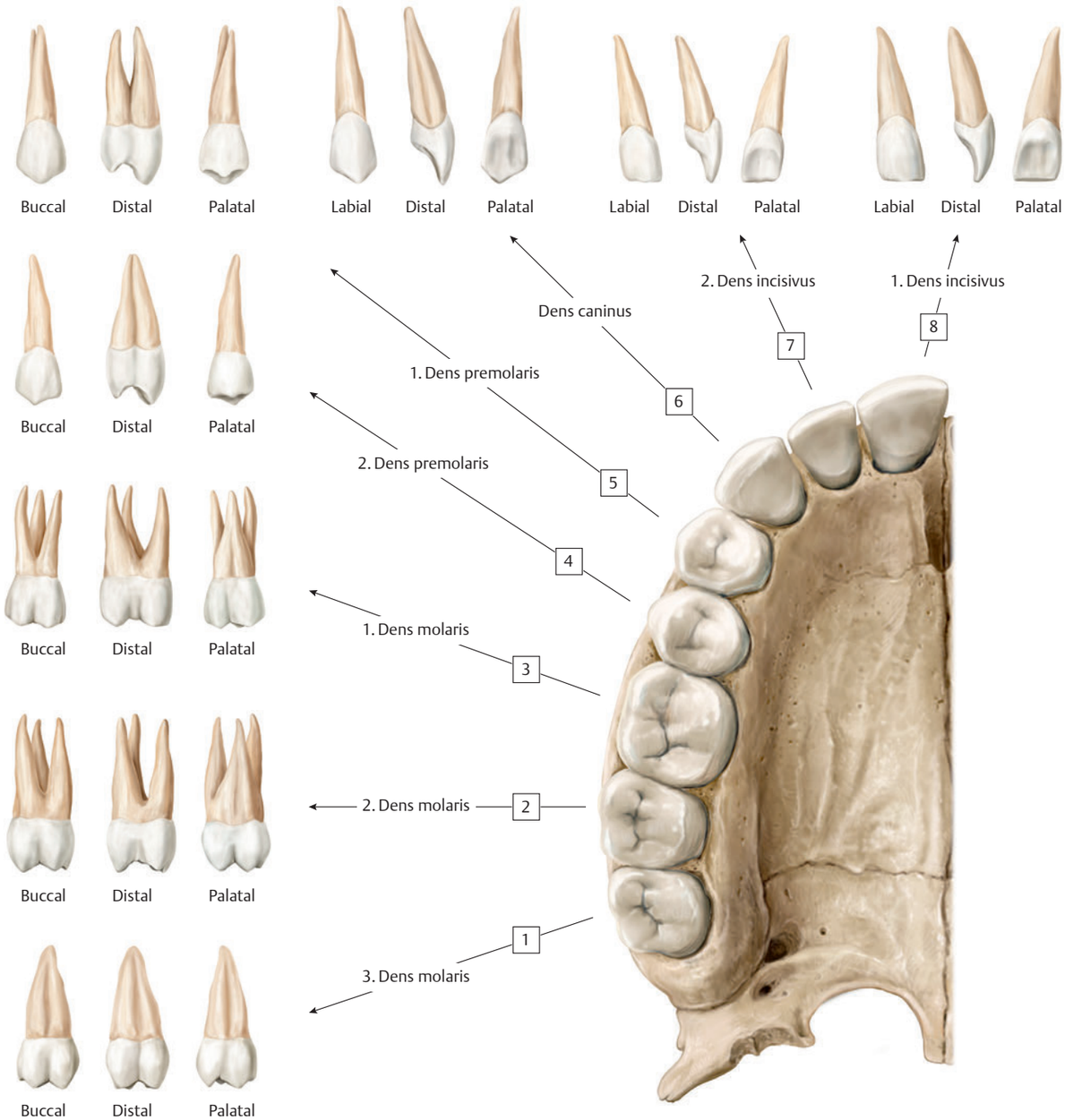


Fig. 8.16 **Morphology of the maxillary dentes permanentes**
Right maxilla, occlusal view and isolated teeth shown in various views.

Dentes incisivi: Dentes incisivi are used for cutting off chunks of food. Accordingly, they are sharp-edged (scoop-shaped). In addition, they largely determine the esthetic appearance of the oral region. In general, all dentes incisivi are single-rooted and have one canalis radicis dentis. The upper central dens incisivus is the largest, the lower central dens incisivus the smallest. The palatal surfaces of the two upper incisors often bear a blind pit, the foramen caecum linguae, which is a site of predilection for dental caries. The maxillary dentes incisivi are considerably larger than the mandibulardentes incisivi, resulting in a cusp-and-fissure occlusion (see **Fig 8.18**).

Dentes canini: Dentes canini consist of a single cuspis dentis. Typically they have one long root (the longest root of all teeth) containing one canalis radicis dentis, and they support the dentes incisivi. Eruption of the maxillary dens caninus tends to correct the splayed orientation of the maxillary lateral dens incisivus and any median diastema (space between the two maxillary central dentes incisivi) and so often orthodontic treatment is delayed until this tooth erupts to monitor how much the teeth will "self-correct". The dentes canini (both maxillary and mandibular) also play an important role in occlusion.

Dentes premolares: Dentes premolares represent a transitional form between the dentes incisivi and the dentes molares. They have cuspides and fissurae occlusales. They are more important in grinding than in biting off food. Maxillary dentes premolares have two cuspides, one buccal and one palatal, separated by a central fissura occlusalis. The first maxillary dens premolaris has two radices dentales, each containing a canalis radicis dentis. The second maxillary dens premolaris typically has one radix dentis, but this may contain one or two canales radicis dentis.

Dentes molares: Dentes molares are the largest of the dentes permanentes and have an facies occlusalis with multiple cuspides. In order to absorb the powerful chewing pressure, the maxillary dentes molares have three radices dentis, each of which contains a canalis radicis dentis (although the radix mesialis may contain two canales radicis dentis). Third dentes molares (dentes serotini) are the exception. The roots of third dentes molares are often fused and therefore their root canal system is complex (canalis radicis therapy is rarely attempted in these teeth).

Table 8.2 **Morphology of the maxillary dentes permanentes**

Tooth	Corona dentis	Facies	Radices dentis	Canales radicis dentis
Central dentes incisivi (8, 9) Lateral dentes incisivi (7, 10)	Roughly trapezoidal in the labial view; contains an incisal edge with 3 tubercula dentis (mammillae)	Facies labialis: convex Facies palatinalis: concavoconvex	1 rounded radix	Usually 1
Dentes canini (6, 11)	Roughly trapezoidal with 1 labial cuspis dentis	Facies labialis: convex Facies palatinalis: concavoconvex	1 radix; the longest of the teeth	Usually 1
1st dens premolaris (5, 12)	2 cuspides (1 cuspis buccalis, 1 cuspis palatinalis), separated by a central fissura occlusalis	Facies buccalis, distalis, palatinalis, and mesialis: all convex, slightly flattened. The facies mesialis often bears a small pit that is difficult to clean and vulnerable to caries Facies occlusalis: more oval than the mandibular dentes premolares	2 radices (1 buccalis, 1 palatalis)	Usually 2, one per root
2nd dens premolaris (4, 13)			1 radix divided by a longitudinal groove and containing 2 canales radicis	1 or 2
1st dens molaris (3, 14)	4 cuspides (1 at each corner of its facies occlusalis); a ridge connects the cuspides mesiopalatalis and distobuccalis	Facies buccalis, distalis, palatinalis, and mesialis: all convex, slightly flattened Facies occlusalis: rhomboid	3 radices (2 buccales, 1 palatalis)	3 or 4 (radix mesialis may have 2 canals)
2nd dens molaris (2, 15)	4 cuspides (though the distopalatal is often small or absent)		3 radices (2 buccales, 1 palatalis), occasionally fused	3 or 4 (radix mesialis may have 2 canals)
3rd dens molaris (1, 16)	3 cuspides (no distopalatal)		3 radices (2 buccales, 1 palatalis), often fused	Complex canal system

The maxillary teeth are supplied by the arteria alveolaris superior posterior (dentes molares), arteria alveolaris superior media (dentes premolares), and the arteriae alveolares superiores anteriores (dentes incisivi and canini); venous drainage is via the venae alveolares that drain to the plexus pterygoideus. Innervation is via the nervi alveolares superiores posteriores, medius, and anteriores (same distribution as the arteries). Lymph from the maxillary teeth drains to the nodi submandibulares.

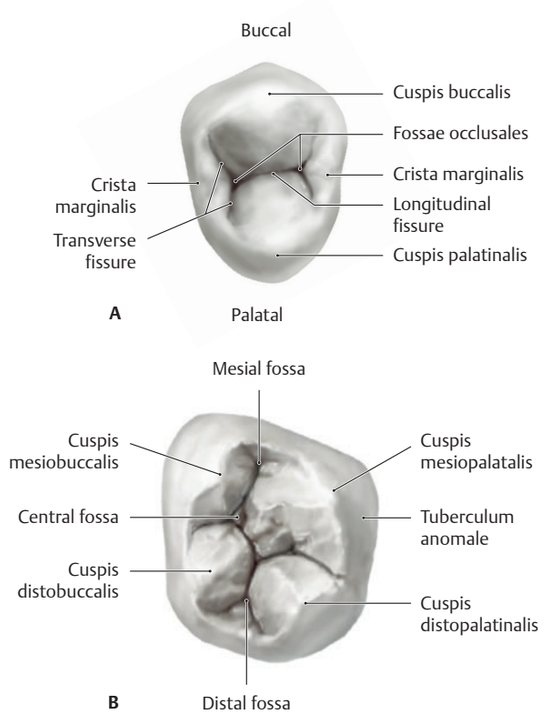


Fig. 8.17 **Maxillary first dens premolaris and first dens molaris**
Occlusal view.

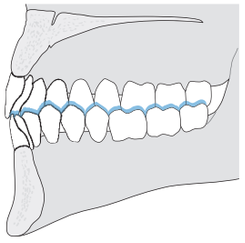


Fig. 8.18 **Cusp-and-fissure occlusion**
With the mouth closed (occlusal position), the maxillary teeth are opposed to their mandibular counterparts. They are offset relative to one another such that the cuspides of one tooth fit into the fissurae occlusales of the two opposing teeth (cusp-and-fissure occlusion). Because of this arrangement, every tooth comes into contact with two opposing teeth. This offset results from the slightly greater width of the maxillary dentes incisivi.
A class I occlusion is a "normal" occlusion where the lower anterior teeth occlude with the cingulum of the upper anterior teeth. A class II occlusion is when the lower teeth occlude behind the cingulum of the upper anterior teeth. A class III occlusion is when the lower anterior teeth occlude in front of the cingulum of the upper anterior teeth. Crossbites are when the teeth are not in the usual buccal-lingual relationship.

Mandibular Dentes Permanentes

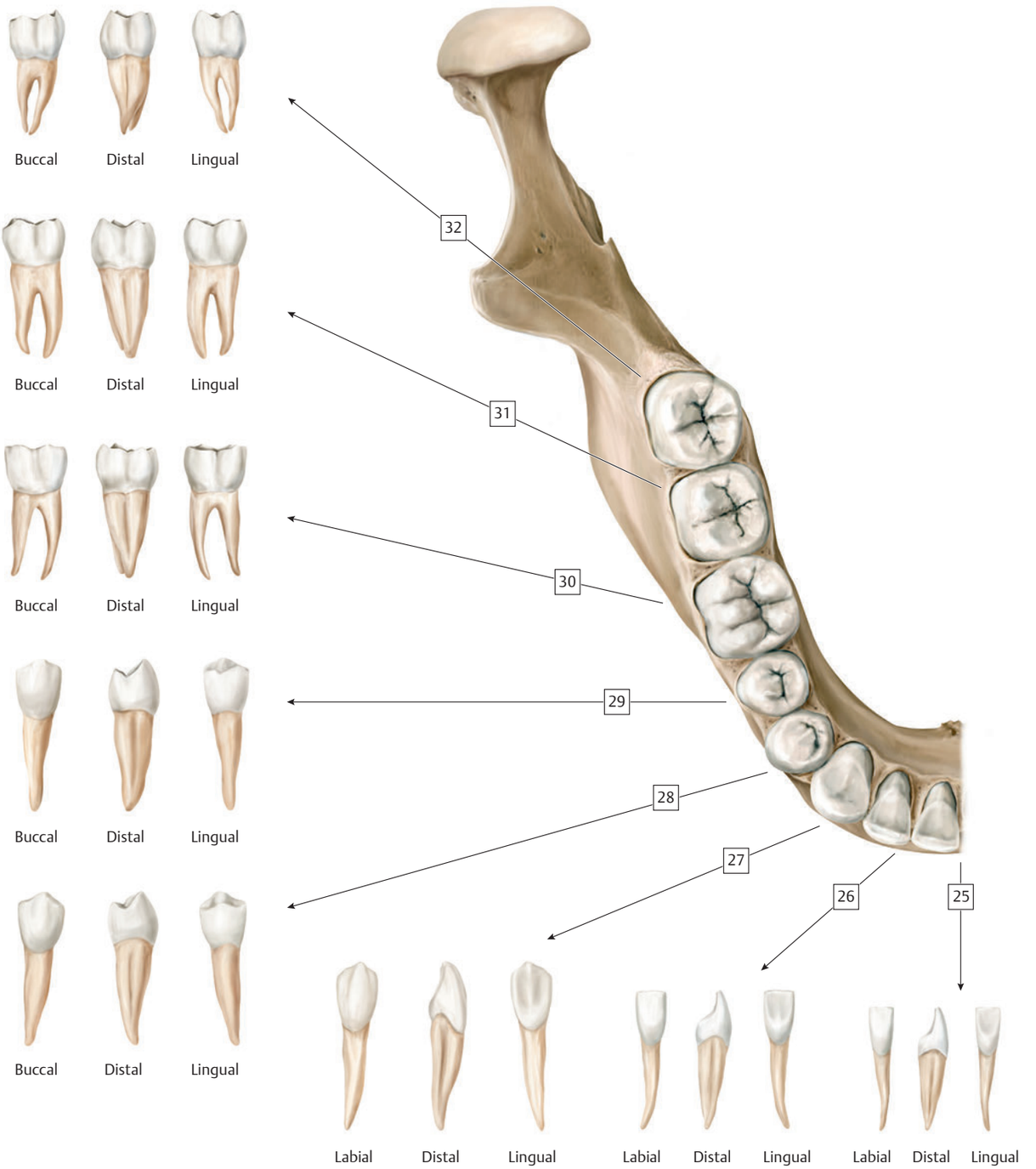


Fig. 8.19 **Morphology of the mandibular dentes permanentes**
The general morphology of the mandibular teeth is similar to that of the maxillary teeth.
Dentes incisivi: Mandibular dentes incisivi are smaller than their maxillary counterparts but have one radix dentis containing one canalis radicis dentis.
Dentes canini: The mandibular dens caninus is similar to the maxillary dens caninus.
Dentes premolares: The mandibular first dens premolaris has a less well defined lingual cuspis. It typically has one radix with one canalis radicis dentis.
Dentes molares: Mandibular first dentes molares have five cuspides, two radices, and between two and four canales radicis dentis. Mandibular second dentes molares have four cuspides but are otherwise similar to the first dentes molares. Mandibular third dentes molares are often impacted (do not erupt into the arcus dentalis) and have two fused radices with a complex canal system.

Table 8.3 **Morphology of the mandibular dentes permanentes**

Tooth	Corona dentis	Facies	Radices dentis	Canales radicis dentis
Central dentes incisivi (24, 25) Lateral dentes incisivi (23, 26)	Roughly trapezoidal in the labial view; contains an incisal edge with 3 tubercula (mammillae)	Facies labialis: convex Facies lingualis: concavoconvex	1 radix, slightly flattened	1
Dentes canini (22, 27)	Roughly trapezoidal with 1 labial cuspis	Facies labialis: convex Facies lingualis: concavoconvex	1 radix; the longest of the teeth (*Note:* mandibular dentes canini are occassionally bifid)	1
1st dens premolaris (21, 28)	2 cuspides (1 tall cuspis buccalis connected to 1 smaller cuspis lingualis; the groove between the cuspides creates a fossa occlusalis mesialis and distalis.	Facies buccalis, distalis, lingualis, and mesialis: all convex, slightly flattened. The facies mesialis often bears a small pit that is difficult to clean and vulnerable to caries Facies occlusalis: more oval than the mandibular dentes premolares mandibular dentes premolares	1 radix (occasaionally bifid)	1
2nd dens premolaris (20, 29)	3 cuspides (1 tall cuspis buccalis separated from 2 cuspides linguales by a mesiodistal fissure)		1 radix	1
1st dens molaris (19, 30)	5 cuspides (3 buccales and 2 linguales), all of which are separated by fissures	Facies buccalis, distalis, lingualis, and mesialis: all convex, slightly flattened Facies occlusalis: rectangular	2 radices (1 mesialis and 1 distalis); widely spaced	2–4
2nd dens molaris (18, 31)	4 cuspides (2 buccales; 2 linguales)		2 radices (1 mesialis and 1 distalis)	2–4
3rd dens molaris (17, 32)	May resemble either the 1st or 2nd dens molaris		2 radices, often fused	Complex canal system

The mandibular teeth are supplied by the arteria alveolaris inferior (dentes molares and premolares) or its incisive branch (dentes incisivi and canini); venous drainage is via the vena alveolaris inferior, which drains to the plexus pterygoideus. Innervation is via the nervus alveolaris inferior (dentes molares and dens premolaris) or its incisive branch (dentes incisivi, canini, and first dentes premolares). Lymph from these teeth drains to the nodi submandibulares.

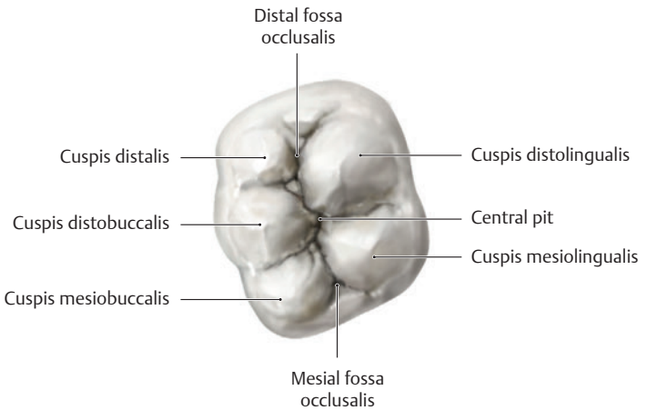


Fig. 8.20 **Mandibular first dens molaris**
Occlusal view.

Dentes Decidui

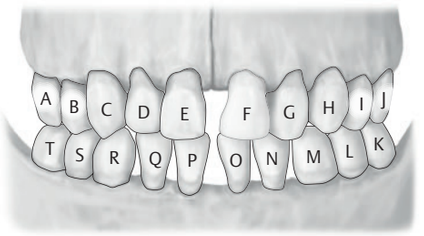


Fig. 8.21 **Coding the dentes decidui**
The upper right dens molaris is considered A. The lettering then proceeds clockwise along the upper arc and back across the lower.

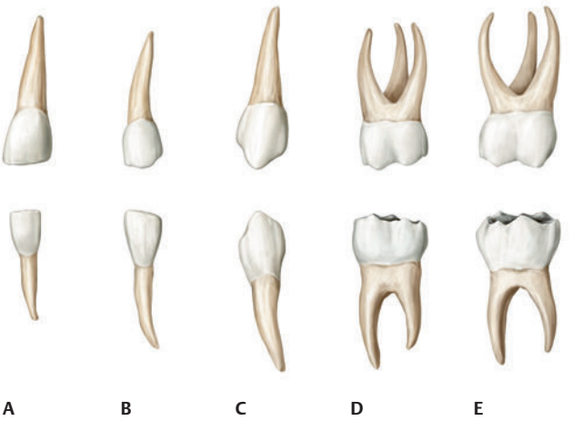


Fig. 8.22 **Dentes decidui**
Left side. The deciduous dentition consists of only 20 teeth. Each of the four quadrants contains the following teeth: **A** Central dens incisivus. **B** Lateral dens incisivus. **C** Dens caninus. **D** First dens molaris. **E** Second dens molaris. To distinguish the dentes decidui from the dentes permanentes, the former are coded with letters. The upper arch is labeled A to J, the lower is labeled K to T.

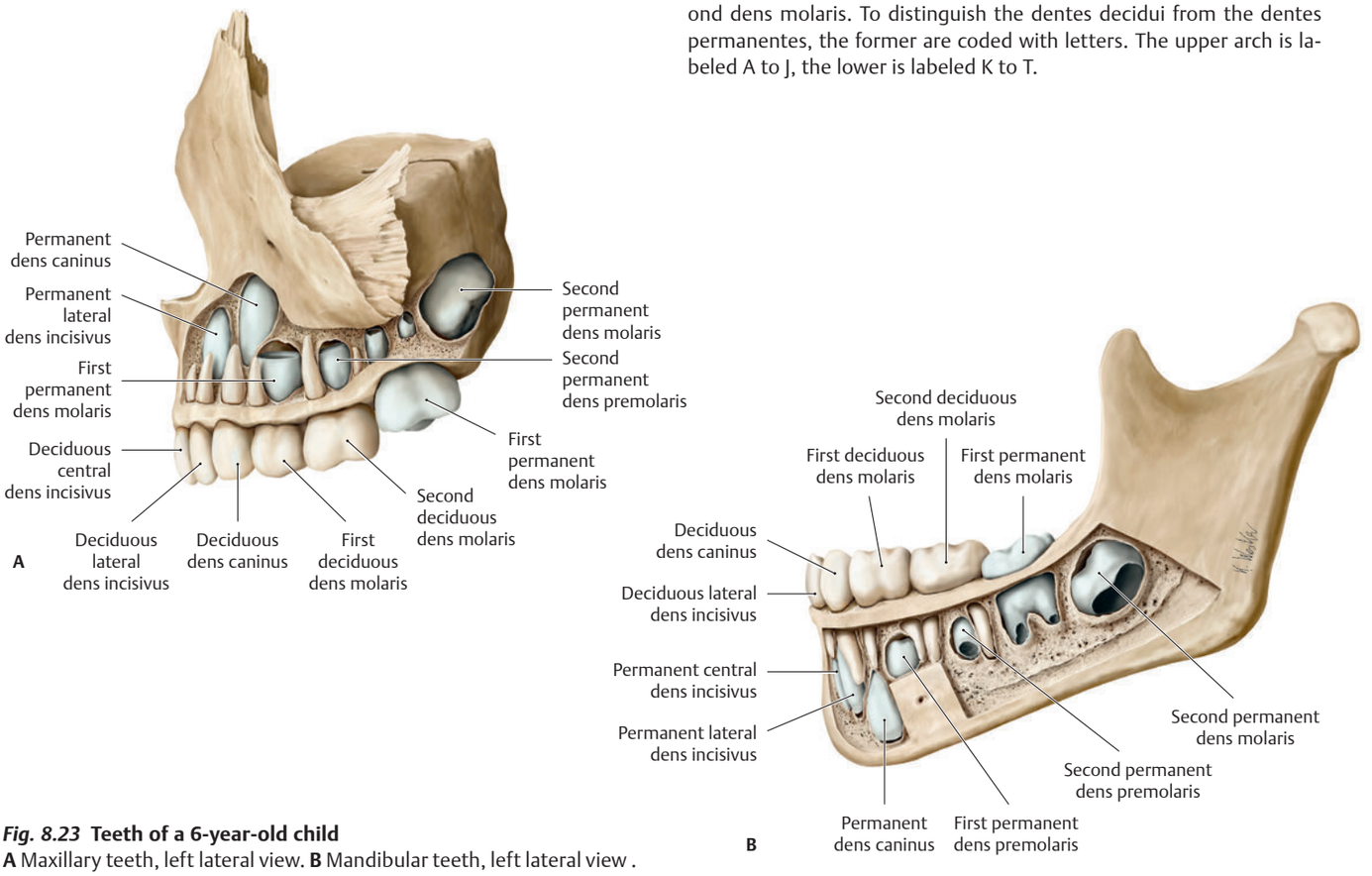


Fig. 8.23 **Teeth of a 6-year-old child**
A Maxillary teeth, left lateral view. **B** Mandibular teeth, left lateral view . The anterior bony plate over the roots of the dentes decidui has been removed to display the underlying permanent tooth buds (blue). At six years of age, all the dentes decidui have erupted and are still present along with the first dens permanens, the first dens molaris.
Note: The roots of deciduous dentes molares are more divergent than those of permanent dentes molares. This is because the permanent dentes premolares form in between these roots and they are guided by them into the dental arch as they erupt. In addition to this difference between dentes decidui and permanentes, dentes decidui have thinner enamelum, larger pulp horns, their pulpal outline follows the cementoenamel junction (CEJ) more closely, they have narrower facies occlusales, broader contact points, thin pulpal floors, and the pulpa within the canales radicis dentis is more tortuous and branching. Furthermore, alveolar bone is more permeable in young children often allowing the clinician to achieve adequate anesthesia via infiltration injections (see p. 470).

Table 8.4 Eruption of the teeth

The eruptions of the dentes decidui and permanentes are called the first and second dentitions, respectively. Types of teeth are ordered by the time of eruption; individual teeth are listed from left to right (viewer's perspective).

Type of tooth	Tooth		Time of eruption
First dentition (dentes decidui)			
Central dens incisivus	E, F	P, O	6–8 months
Lateral dentes incisivus	D, G	Q, N	8–12 months
First dens molaris	B, I	S, L	12–16 months
Dens caninus	C, H	R, M	15–20 months
Second dens molaris	A, J	T, K	20–40 months
Second dentition (dentes permanentes)			
First dens molaris	3, 14	30, 19	6–8 years ("6-yr molar")
Central dens incisivus	8, 9	25, 24	6–9 years
Lateral dens incisivus	7, 10	26, 23	7–10 years
First dens premolaris	5, 12	28, 21	9–13 years
Dens caninus	6, 11	27, 22	9–14 years
Second dens premolaris	4, 13	29, 20	11–14 years
Second dens molaris	2, 15	31, 18	10–14 years ("12-yr molar")
Third dens molaris	1, 16	32, 17	16–30 years ("wisdom tooth")

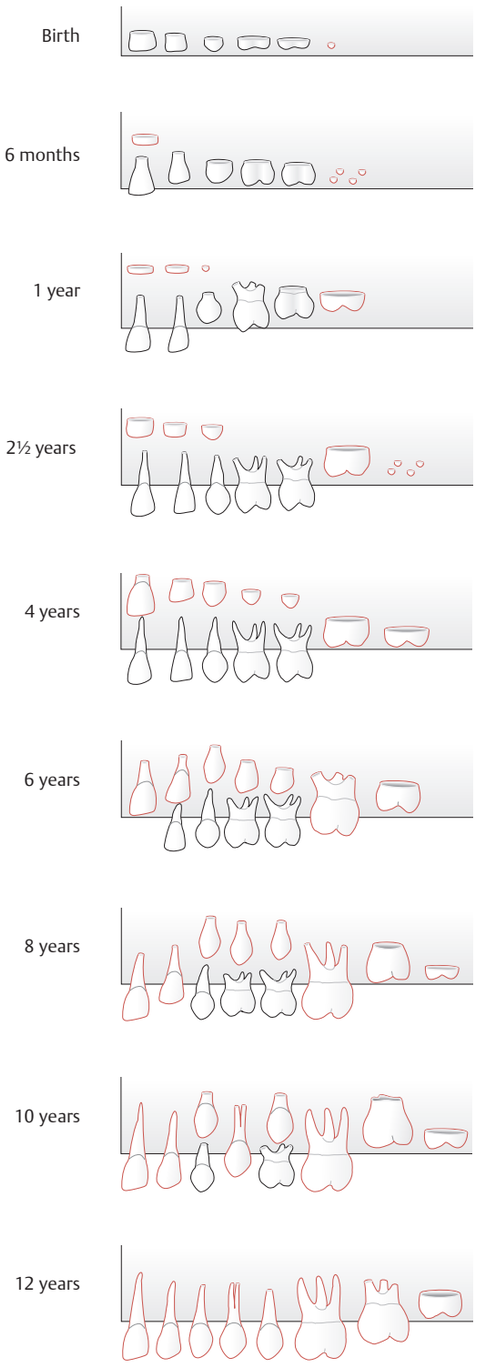
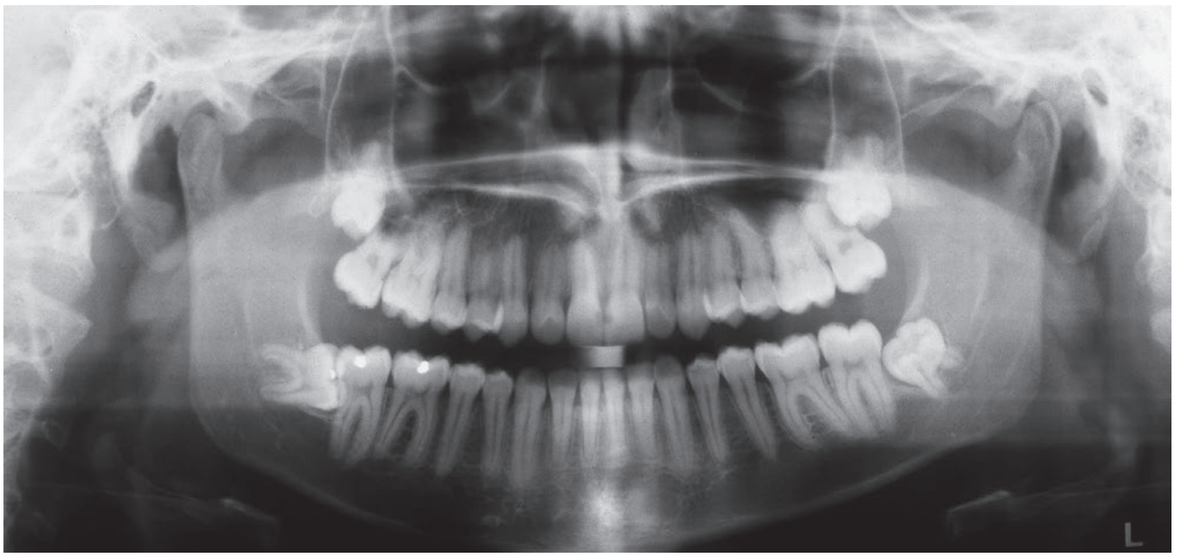


***Fig. 8.24* Eruption pattern of the dentes decidui and permanentes**
Left maxillary teeth. Dentes decidui (black), dentes permanentes (red). Eruption times can be used to diagnose growth delays in children.

Radiographs of Teeth



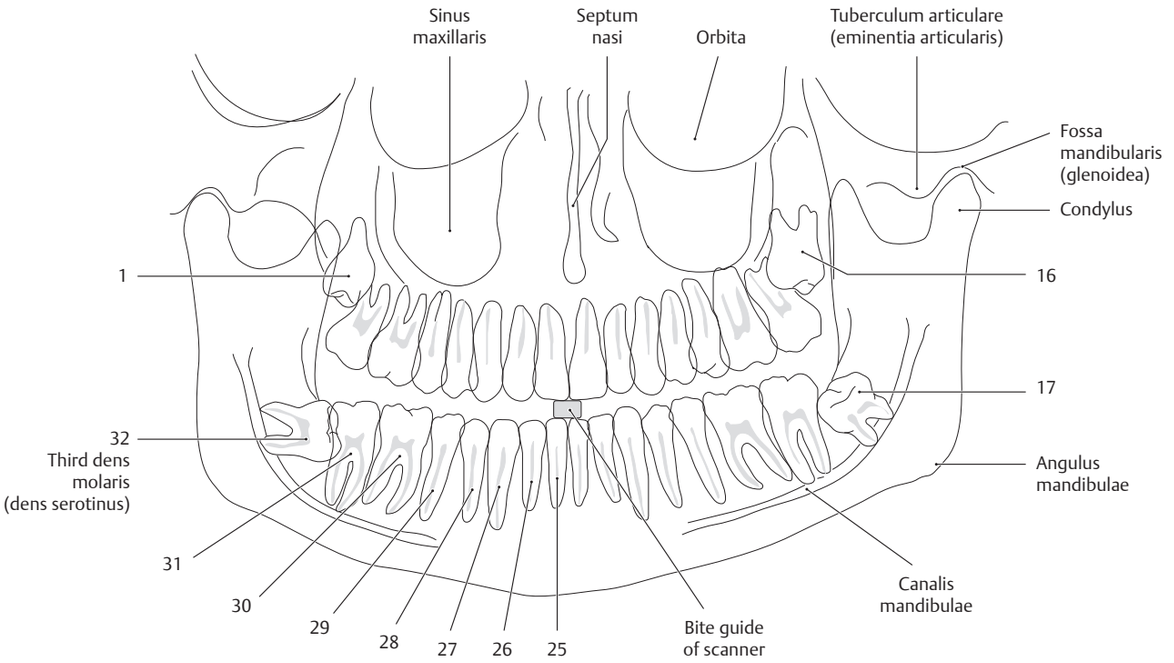


Fig. 8.25 **Dental panoramic tomogram**
The dental panoramic tomogram (DPT) is a survey radiograph that allows a preliminary assessment of the articulationes temporomandibulares, sinus maxillares, maxilla, mandibula, and dental status (carious lesions, location of the dentes serotini). It is based on the principle of conventional tomography in which the X-ray tube and film are moved about the plane of interest to blur out the shadows of structures outside the sectional plane. The plane of interest in the DPT is shaped like a parabola, conforming to the shape of the jaws. If the DPT raises suspicion of caries or root disease, it should be followed with spot radiographs so that specific regions of interest can be evaluated at higher resolution.
(Tomogram courtesy of Prof. Dr. U. J. Rother, director of the Department of Diagnostic Radiology, Center for Dentistry and Oromaxillofacial Surgery, Eppendorf University Medical Center, Hamburg, Germany.)

Generally, radiographic images of the teeth and gums are taken by directing the X-ray beam perpendicular to a tangent to the dental arch, or, to put it more simply, perpendicular to the outer surface of the tooth or teeth. Thus, the radiograph shows all consecutive structures in the beam path and so they overlap. In teeth with multiple roots, the individual canales radicis cannot be clearly evaluated. This is only possible with the help of so-called eccentric images, in which the X-ray beam is directed to the tangent at a particular angle, so that the consecutive structures are clearly distinguishable. Bitewing radiographs (see Fig 8.31) only show the corona dentis of the tooth, and not the entire tooth. The patient bites down on a mount that holds a small piece of film perpendicular to it. The resulting radiograph shows the corona dentis of both maxillary and mandibular teeth in the same radiograph, which helps in detection of caries (tooth decay) underneath fillings or on the contact surfaces. (Radiographs courtesy of Christian Friedrichs, DDM.)

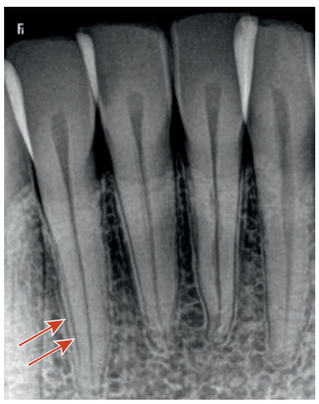


Fig. 8.26 **Mandibular dentes incisivi**
Single-rooted teeth have two canales radicis in one third of all cases. This radiograph shows a cross-section of the dental root and a double periodontal space (see arrows).

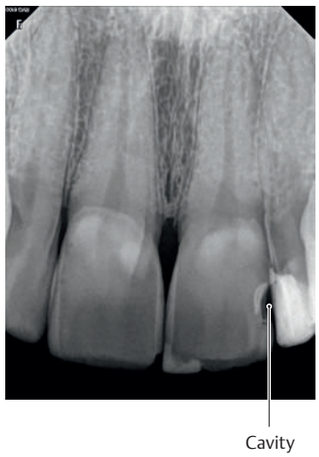


Fig. 8.27 **Maxillary dentes incisivi**
The radioopaque spots shown here distally on tooth 9 could indicate caries, open cavities, or non-radioopaque filling material (as in the case here).

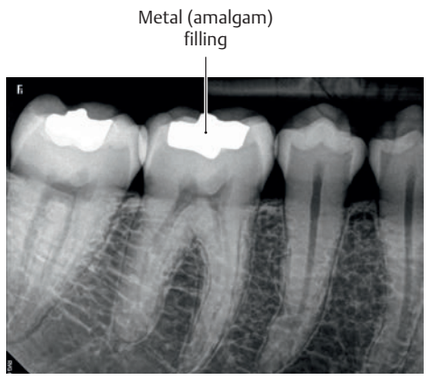


Fig. 8.28 **Mandibular teeth 28–31**
Radiolucencies, such as those seen here near the crowns of teeth 30 and 31, can be the result of metal inlays, crowns, amalgam fillings, or modern zinc oxide ceramics.

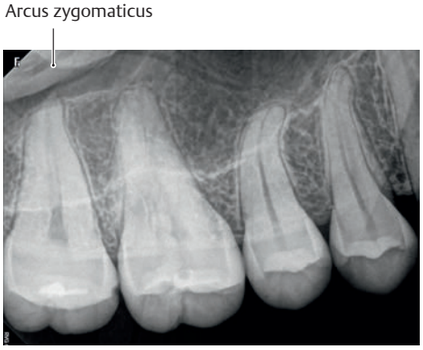


Fig. 8.29 **Maxillary teeth 2–5**
In this area of the maxilla, superimposition of teeth and the arcus zygomaticus frequently occurs (see the upper left margin). The roots of the dentes molares are less clearly visible.

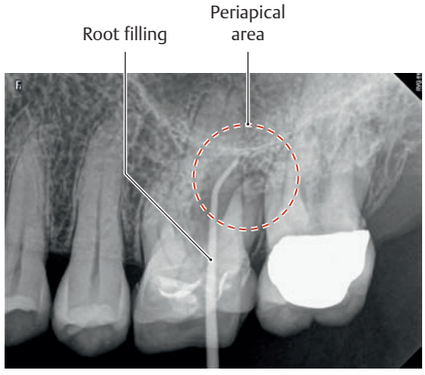


Fig. 8.30 **Maxillary teeth 12–15**
An infection of the canalis radicis system that has spread to the periapical bone can lead to the formation of a fistula. In order to be able to exactly locate the infection, a gutta-percha root-filling point is inserted into the fistula from outside. Around the distobuccal root of tooth 14, a periapical radioopaque area indicating the infection is visible. Tooth 15 has been capped with a crown.

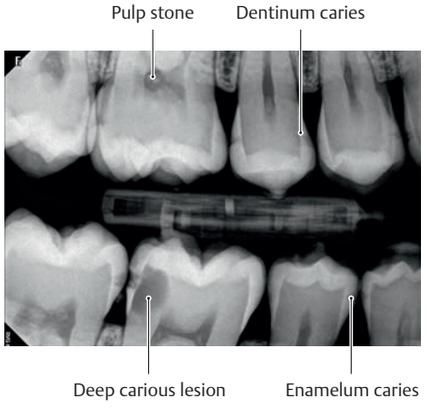


Fig. 8.31 **Bitewings for the diagnosis of caries**
There is massive carious damage on the distal surface of tooth 30 and there are also enamelum caries and the beginning of dentinum caries at the contact points of almost all teeth. In addition to the facies occlusales, the contact points represent sites of predilection for caries. Note the pulp stones visible in the lumen of the cavitates pulpares.

Tunica Mucosa Linguae

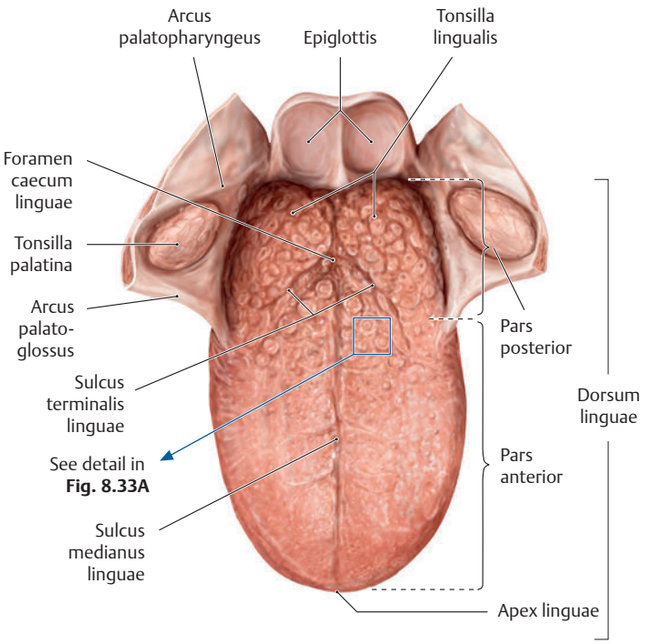


Fig. 8.32 **Surface anatomy of the tunica mucosa linguae**
Superior view. The parts of the tongue are the radix linguae, the facies inferior linguae, the apex linguae, and the dorsum linguae. The V-shaped furrow on the dorsum (sulcus terminalis linguae) divides the dorsal surface into an oral portion (comprising the anterior two thirds) and a pharyngeal portion (comprising the posterior one third).
The tongue's very powerful muscular body make possible its motor functions in mastication, swallowing, and speaking. Its specialized mucosal coat covering the dorsum linguae make possible its equally important sensory functions (including taste and fine tactile discrimination). The human tongue contains approximately 4600 taste buds (caliculi gustatorii), in which the secondary sensory cells for taste perception are collected. The taste buds are embedded in the epithelium of the lingual mucosa and its surface expansions, the papillae linguales (see **Fig 8.33**). Additionally, isolated taste buds are located in the mucous membranes of the palatum molle and pharynx. Humans can perceive five basic taste qualities: sweet, sour, salty, bitter, and umami.

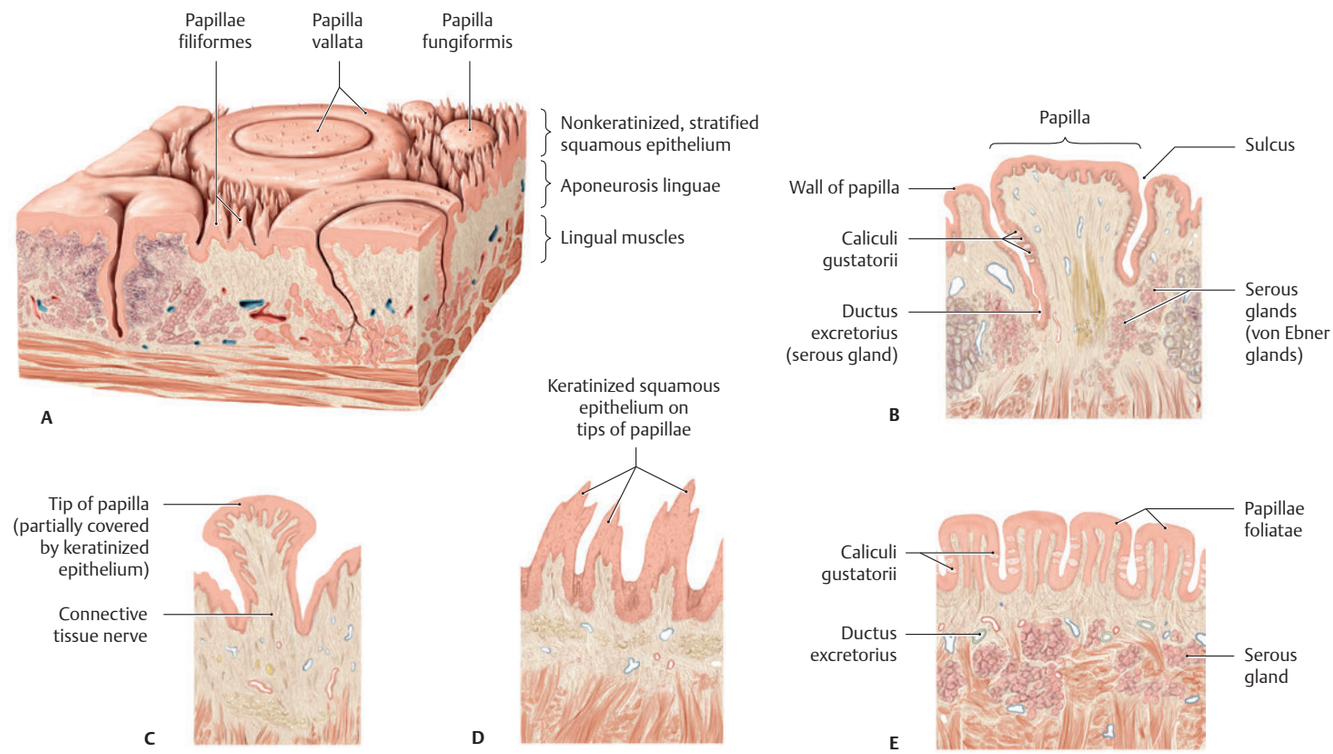


Fig. 8.33 **Papillae of the tongue**
The mucosa of the pars anterior dorsi linguae is composed of numerous papillae (**A**) and the connective tissue between the mucosal surface and musculature, which contains many glandulae salivariae minores. The papillae are divided into four morphologically distinct types (see **Table 8.5**):

- Papillae vallatae (**B**): Encircled and containing caliculi gustatorii.
- Papillae fungiformes (**C**): Mushroom-shaped and containing mechanical and thermal receptors and caliculi gustatorii.
- Papillae filiformes (**D**): Thread-shaped and sensitive to tactile stimuli (the only lingual papillae without caliculi gustatorii).
- Papillae foliatae (**E**): Containing caliculi gustatorii.

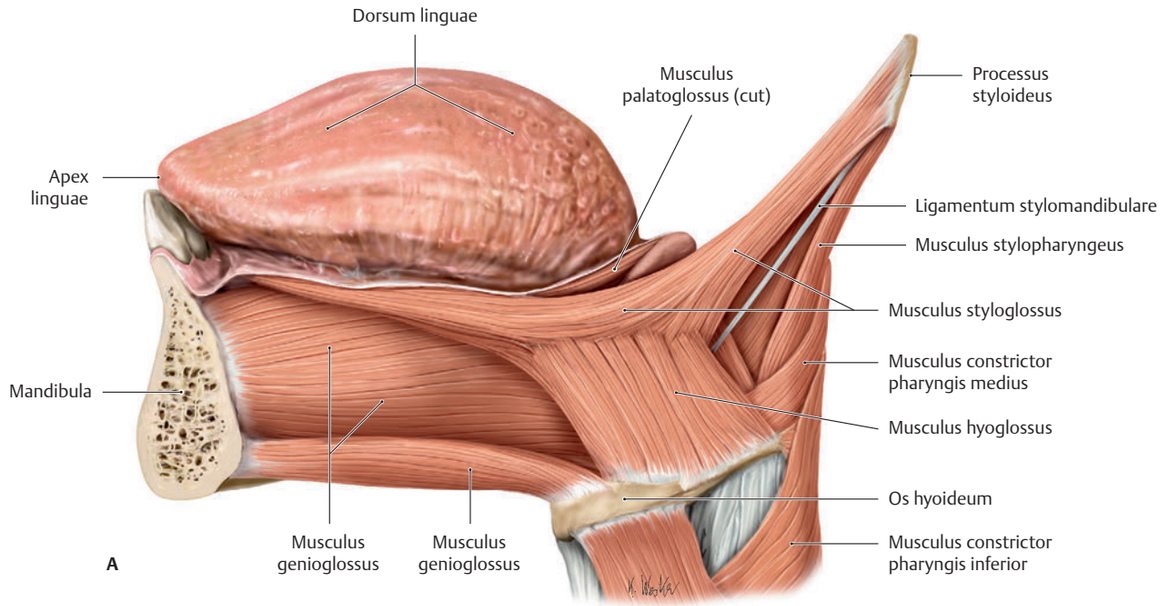
The surrounding serous glands of the tongue (Von Ebner glands), which are most closely associated with papillae vallatae, constantly wash the caliculi gustatorii clean to allow for new tasting.

Table 8.5 **Regions and structures of the tongue**

Region	Structures
Pars anterior (presulcalis) dorsi linguae	
The anterior ⅔ of the tongue contains the apex linguae and the majority of the dorsum linguae. It is tethered to the oral floor by the frenulum linguae. • **Mucosa:** ◦ Dorsal lingual mucosa: This portion (with no underlying submucosa) contains numerous papillae. ◦ Ventral mucosa: Covered with the same smooth (nonkeratinized, stratified squamous epithelial) mucosa that lines the oral floor and gingiva. • **Innervation:** The anterior portion is derived from the first (pharyngeal) arch and is therefore innervated by the nervus lingualis, a branch of the nervus mandibularis (CN V_3).	**Sulcus medianus linguae:** The furrow running anteriorly down the midline of the tongue; this corresponds to the position of the septum linguae. *Note:* Muscle fibers do not cross the septum linguae. **Papillae (Fig. 8.33A):** The dorsal mucosa, which has no submucosa, is covered with nipplelike projections (papillae) that increase the surface area of the tongue. There are four types, all of which occur in the pars presulcalis but not pars postsulcalis linguae. • Papillae vallatae (**Fig. 8.33B**): Encircled by a wall and containing abundant caliculi gustatorii. • Papillae fungiformes (**Fig. 8.33C**): Mushroom-shaped papillae located on the lateral margin of the posterior oral portion near the arci palatoglossi. These have mechanical receptors, thermal receptors, and caliculi gustatorii. • Papillae filiformes (**Fig. 8.33D**): Thread-shaped papillae that are sensitive to tactile stimuli. These are the only papillae that do not contain caliculi gustatorii. • Papillae foliatae (**Fig. 8.33E**): Located near the sulcus terminalis linguae, these contain numerous caliculi gustatorii.
Sulcus terminalis linguae	
The sulcus terminalis linguae is the V-shaped furrow that divides the tongue functionally and anatomically into a pars anterior and a pars posterior.	**Foramen caecum linguae:** The embryonic remnant of the passage of the glandula thyroidea that migrates from the dorsum linguae during development. The foramen caecum linguae is located at the convergence of the sulci terminales linguae.
Pars posterior (postsulcalis) dorsi linguae	
The radix linguae is located posterior to the arci palatoglossi and sulcus terminalis linguae. • **Mucosa:** The same mucosa that lines the tonsillae palatinae, pharyngeal walls, and epiglottis. The pars posterior dorsi linguae does not contain papillae. • **Innervation:** The posterior portion is innervated by the nervus glossopharyngeus (CN IX). A small midline area at the root of the tongue is innervated by the nervus vagus (CN X)	**Tonsillae linguales:** The submucosa of the pars posterior dorsi linguae contains embedded lymph nodes known as the tonsillae linguales, which create the uneven surface of the posterior portion. **Pars oralis pharyngis:** The region posterior to the arcus palatoglossus. The pars oralis pharyngis, which contains the tonsillae palatinae, communicates with the cavitas oris via the isthmus faucium (defined by the arci palatoglossi).
Plicae glossoepiglotticae and valleculae epiglotticae: The (nonkeratinized, stratified squamous) mucosal covering of the posterior tongue and pharyngeal walls is reflected onto the anterior aspect of the epiglottis, forming one plica glossoepiglottica mediana and two plicae glossoepiglotticae laterales. The plica glossoepiglottica mediana is flanked by two depressions, the valleculae epiglotticae.	

Musculi Linguae

There are two sets of lingual muscles: extrinsic and intrinsic. The extrinsic muscles, which are attached to specific bony sites outside the tongue, move the tongue as a whole. The intrinsic muscles, which have no attachments to skeletal structures, alter the shape of the tongue. With the exception of the musculus palatoglossus, the glossal muscles are innervated by the nervus hypoglossus (CN XII).



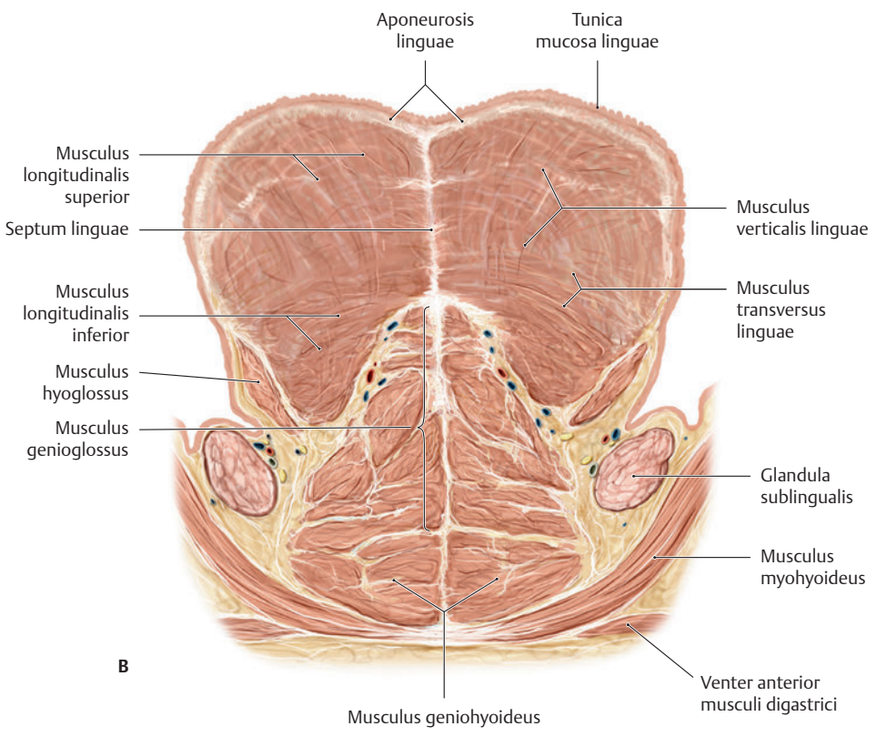


Fig. 8.34 **Extrinsic and intrinsic lingual muscles**
A Left lateral view. **B** Anterior view of coronal section.

Table 8.6 **Muscles of the tongue**

Muscle	Origin	Insertion	Innervation	Action
Extrinsic lingual muscles				
Musculus genioglossus	Mandibula (Spina mentalis (geni) superior via an intermediate tendon); more posteriorly the two musculi genioglossi are separated by the septum linguae	Inferior fibers: Corpus ossis hyoidei (anterosuperior surface)	Nervus hypoglossus (CN XII)	Protrusion of the tongue *Bilaterally:* Makes dorsum concave *Unilaterally:* Deviation to opposite side
		Intermediate fibers: Posterior tongue		
		Superior fibers: Ventral surface of tongue (mix with intrinsic muscles)		
Musculus hyoglossus	Os hyoideum (cornu majus and anterior corpus ossis hyoidei)	Lateral tongue, between musculus styloglossus and musculus longitudinalis inferior		Depresses the tongue
Musculus styloglossus	Processus styloideus ossis temporalis (anterolateral aspect of apex) and ligamentum stylomandibulare	Longitudinal part: Dorsolateral tongue (mix with musculus longitudinalis inferior)		Elevates and retracts the tongue
		Oblique part: Mix with fibers of the musculus hyoglossus		
Musculus palatoglossus	Aponeurosis palatina (oral surface)	Lateral tongue to dorsum linguae and fibers of the musculus transversus linguae	Nervus vagus (CN X) via the plexus pharyngeus	Elevates the radix linguae; closes the isthmus faucium by contracting the arcus palatoglossus
Intrinsic lingual muscles				
Musculus longitudinalis superior	Thin layer of muscle inferior to the dorsal mucosa; fibers run anterolaterally from the epiglottis and median septum linguae		Nervus hypoglossus (CN XII)	Shortens tongue; makes dorsum concave (pulls apex and lateral margin upward)
Musculus longitudinalis inferior	Thin layer of muscle superior to the musculi genioglossus and hyoglossus; fibers run anteriorly from the root to the apex of the tongue			Shortens tongue; makes dorsum convex (pulls apex down)
Musculus transversus linguae	Fibers run laterally from the septum linguae to the lateral tongue			Narrows tongue; elongates tongue
Musculus verticalis linguae	In the anterior tongue, fibers run inferiorly from the dorsum linguae to its ventral surface			Widens and flattens tongue

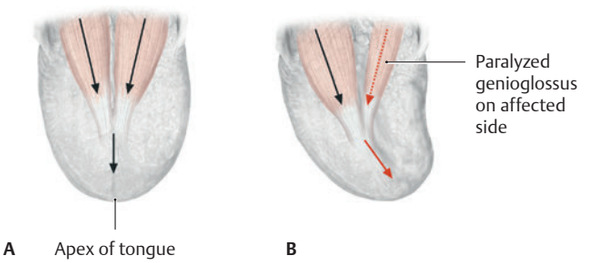
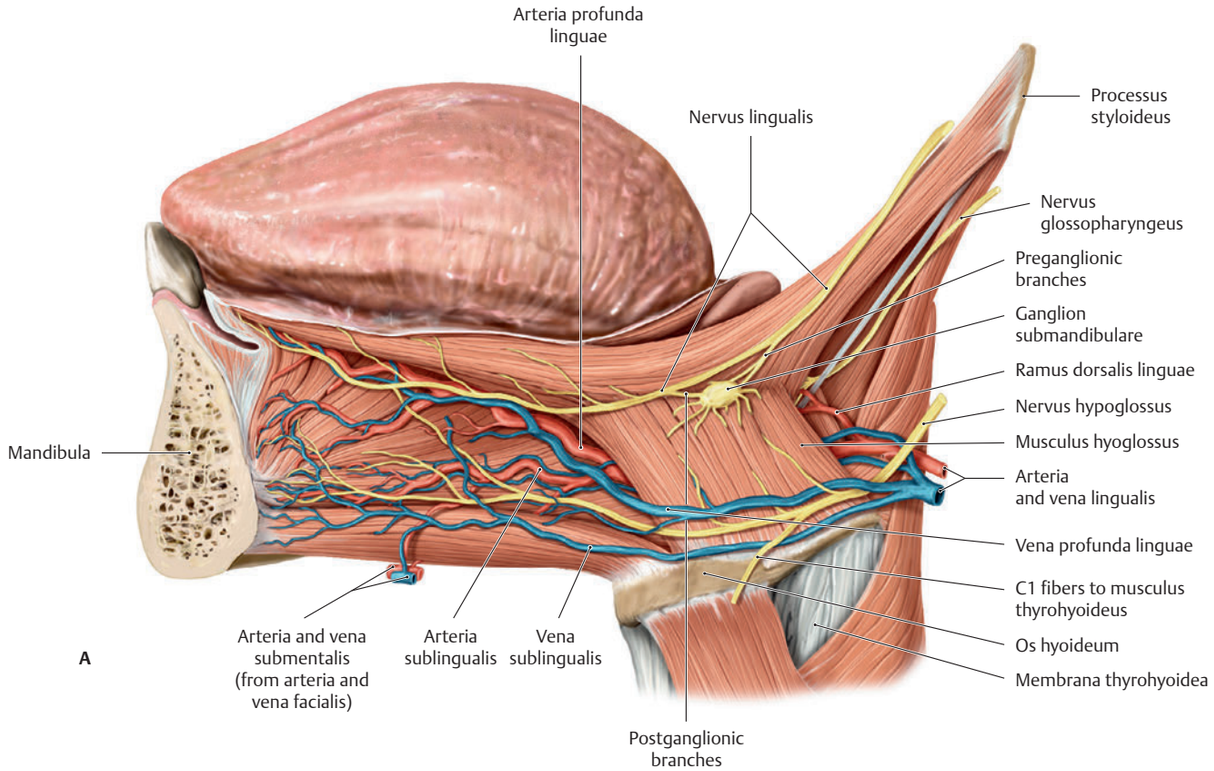


Fig. 8.35 **Unilateral hypoglossal nerve palsy**
Active protrusion of the tongue with an intact nervus hypoglossus (**A**) and with a unilateral nervus hypoglossus lesion (**B**).
When the nervus hypoglossus is damaged on one side, the musculus genioglossus is paralyzed on the affected side. As a result, the healthy (innervated) musculus genioglossus on the opposite side dominates the tongue across the midline toward the affected side. When the tongue is protruded, therefore, it deviates *toward* the paralyzed side.

Neurovasculature of the Tongue



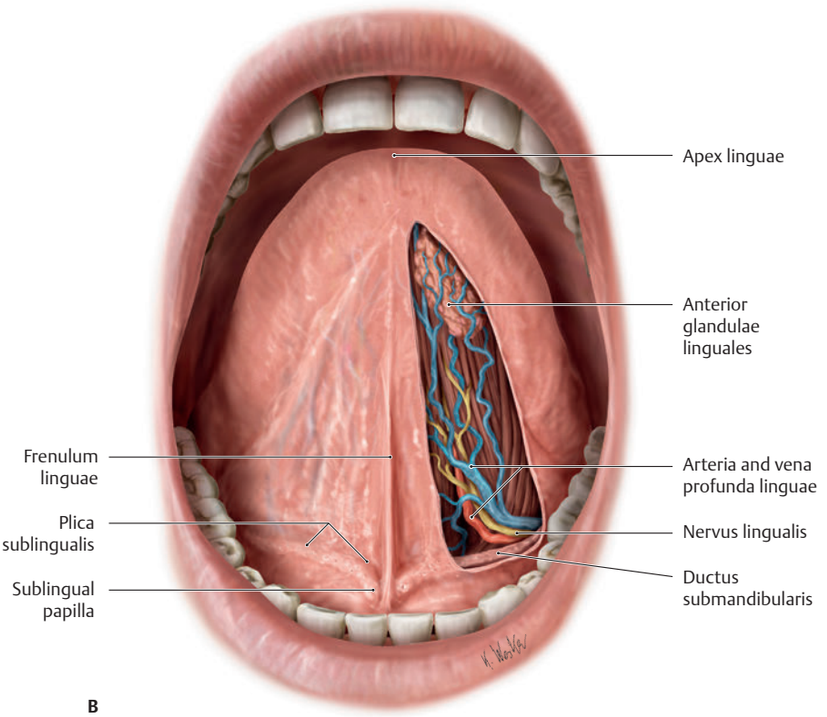


Fig. 8.36 **Nerves and vessels of the tongue**
A Left lateral view. **B** View of the facies inferior linguae.

The tongue is supplied by the *arteria lingualis* (from the arteria carotis externa), which divides into its terminal branches, the arteria profunda linguae and the arteria sublingualis. The rami dorsales linguae supply the radix linguae in the pars oralis pharyngis. The vena lingualis usually runs parallel to the artery but on the medial surface of the musculus hyoglossus and drains into the *vena jugularis interna*. The anterior two thirds of the tunica mucosa linguae receives its *somatosensory* innervation (sensitivity to thermal and tactile stimuli) from the *nervus lingualis*, which is a branch of the nervus trigeminus mandibular division (CN V_3). The nervus lingualis transmits fibers from the chorda tympani of the nervus facialis (CN VII), among them the afferent taste fibers for the anterior two thirds of the tongue. The chorda tympani also contains presynaptic, parasympathetic visceromotor axons that synapse in the ganglion submandibulare, whose neurons in turn innervate the glandulae submandibularis and sublingualis. The musculus palatoglossus receives its *somatomotor* innervation from the nervus vagus (CN X) via the plexus pharyngeus, the other glossal muscles from the nervus hypoglossus (CN XII).

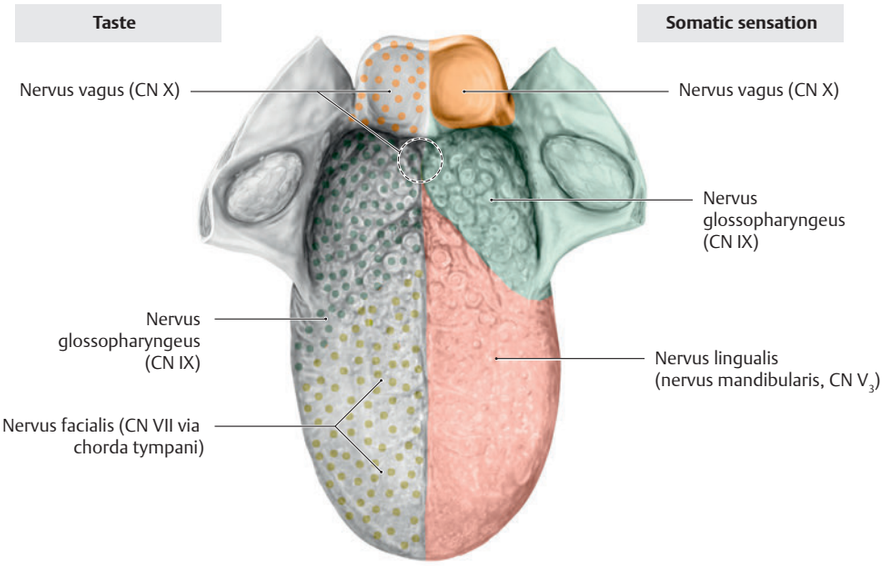


***Fig. 8.37* Innervation of the tongue**
Anterior view. Left side: Somatosensory innervation. Right side: Taste innervation.
The posterior one third of the tongue (pars postsulcalis) primarily receives somatosensory and taste innervation from the nervus glossopharyngeus (CN IX), with additional taste sensation conveyed by the nervus vagus (CN X) via the ramus internus nervi laryngei superioris.
The anterior two thirds of the tongue (pars presulcalis) receives its somatosensory innervation (e.g., touch, pain, and temperature) from the nervus lingualis (branch of CN V_3) and its taste sensation from the chorda tympani branch of the nervus facialis (CN VII) distributed by the nervus lingualis (CN V_3). Disturbances of sensation in thepars presulcalis linguae can therefore be used to determine nervus facialis or trigeminus nerve lesions.

***Table 8.7* Blood supply to the tongue**

Blood supply	Source	Branches	Distribution
Arteria lingualis	Arteria carotis externa	Rami dorsales linguae	Pars posterior dorsi linguae, arcus palatoglossus, tonsilla palatina, epiglottis, palatum molle
		Arteria sublingualis	Floor of cavitas oris, glandula sublingualis and surrounding mucosa and muscles
		Arteria profunda linguae	Facies inferior linguae of tongue
		Terminal branches	Pars anterior dorsi linguae
Arteria submentalis	Arteria facialis (from arteria carotis externa)		Anatomoses with arteria sublingualis to supply glandula sublingualis and surrounding floor of mouth
Ramus tonsillaris	Arteria facialis (from arteria carotis externa)		Radix linguae
Arteria pharyngea ascendens	Arteria carotis externa		Radix linguae

***Table 8.8* Venous drainage of the tongue**

Vein	Tributaries	Region drained	Drains to
Vena lingualis	Vena profunda linguae	Facies inferior linguae	Vena jugularis interna
	Venae dorsales linguae	Dorsum linguae	
Vena submentalis		Anatomoses with branches of venae linguales to help drain tongue	Vena facialis

Gustatory Pathway

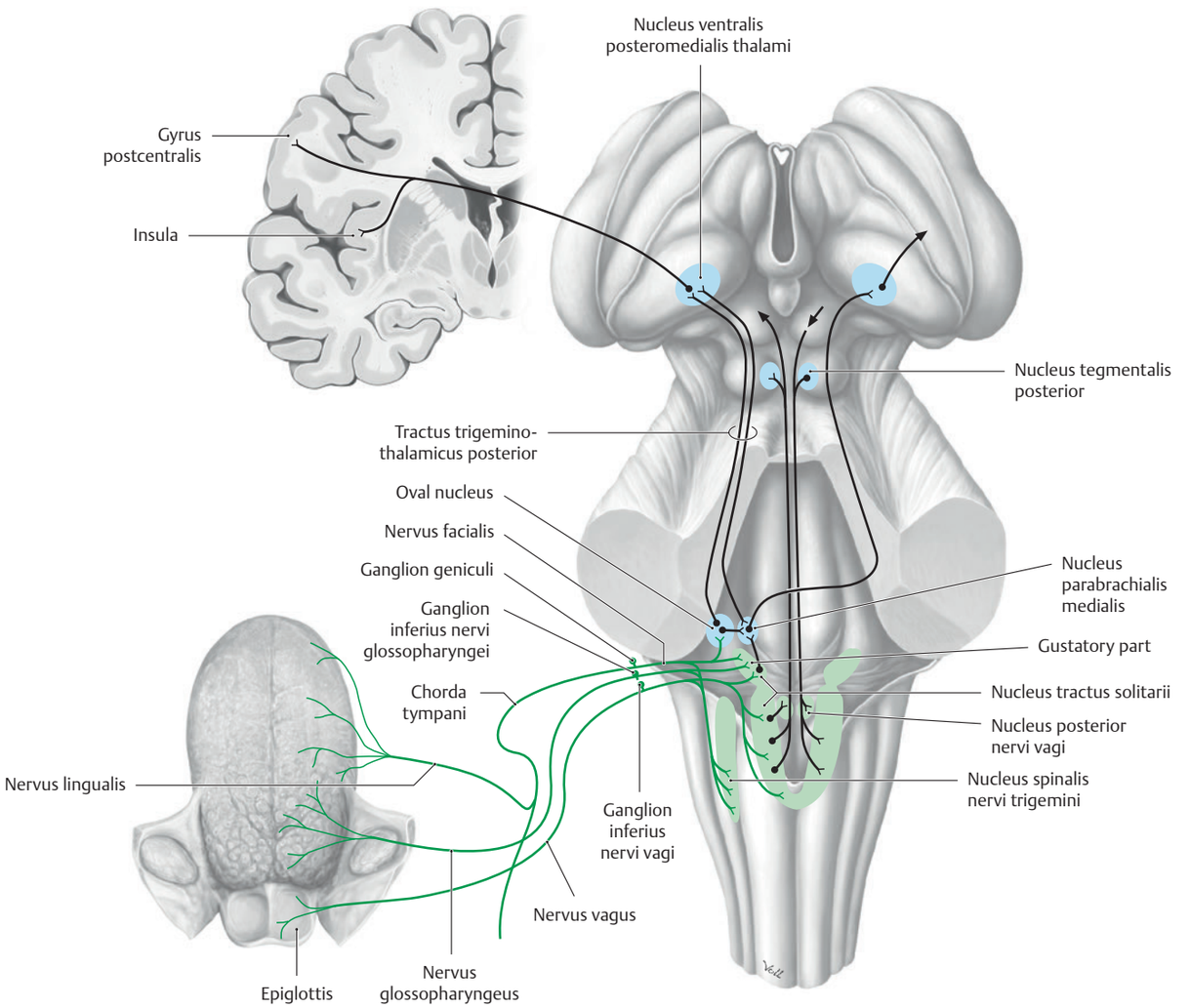


Fig. 8.38 **Gustatory pathway**
The receptors for the sense of taste are the caliculi gustatorii of the tongue (see **Fig. 8.39**). Unlike other receptor cells, the receptor cells of the caliculi gustatorii are specialized epithelial cells (secondary sensory cells, as they do not have an axon). When these epithelial cells are chemically stimulated, the base of the cells releases glutamate, which stimulates the peripheral processes of afferent cranial nerves. These different cranial nerves serve different areas of the tongue. It is rare, therefore, for a complete loss of taste (ageusia) to occur.

- The *pars anterior* dorsi linguae is supplied by the nervus facialis (CN VII), the afferent fibers first passing in the nervus lingualis (branch of the nervus trigeminus) and then in the chorda tympani to the ganglion geniculi of the nervus facialis.
- The *pars posterior dorsi linguae* and the *papillae vallatae* are supplied by the nervus glossopharyngeus (CN IX). A small area on the pars posterior dorsi linguae is also supplied by the nervus vagus (CN X).
- The *epiglottis* and *valleculae* are supplied by the nervus vagus (CN X).

Peripheral processes from pseudounipolar ganglion cells (which correspond to pseudounipolar spinal ganglion cells) terminate on the caliculi gustatorii. The central portions of these processes convey taste information to the gustatory part of the nucleus of the tractus solitarius. Thus, they function as the first afferent neuron of the gustatory pathway. Their cell bodies are located in the ganglion geniculi for the nervus facialis, in the ganglion inferius for the nervus glossopharyngeus, and in the ganglion inferius for the nervus vagus. After synapsing in the gustatory part of the nucleus tractus solitarii, the axons from the second neuron are believed to terminate in the nucleus parabrachialis medialis, where they are relayed to the third neuron. Most of the axons from the third neuron cross to the opposite side and pass in the tractus trigeminothalamicus posterior to the contralateral nucleus ventralis posteromedialis of the thalamus. Some of the axons travel uncrossed in the same structures. The fourth neurons of the gustatory pathway, located in the thalamus, project to the gyrus postcentralis and insular cortex, where the fifth neuron is located. Collaterals from the first and second neurons of the gustatory afferent pathway are distributed to the nuclei salivatorii superior and inferior. Afferent impulses in these fibers induce the secretion of saliva during eating (“salivary reflex”). The parasympathetic preganglionic fibers exit the brainstem via cranial nerves VII and IX (see the descriptions of these cranial nerves for details). Besides this purely gustatory pathway, spicy foods may also stimulate trigeminal fibers (not shown), which contribute to the sensation of taste. Finally, olfaction (the sense of smell), too, is a major component of the sense of taste as it is subjectively perceived: patients who cannot smell (anosmia) report that their food tastes abnormally bland.

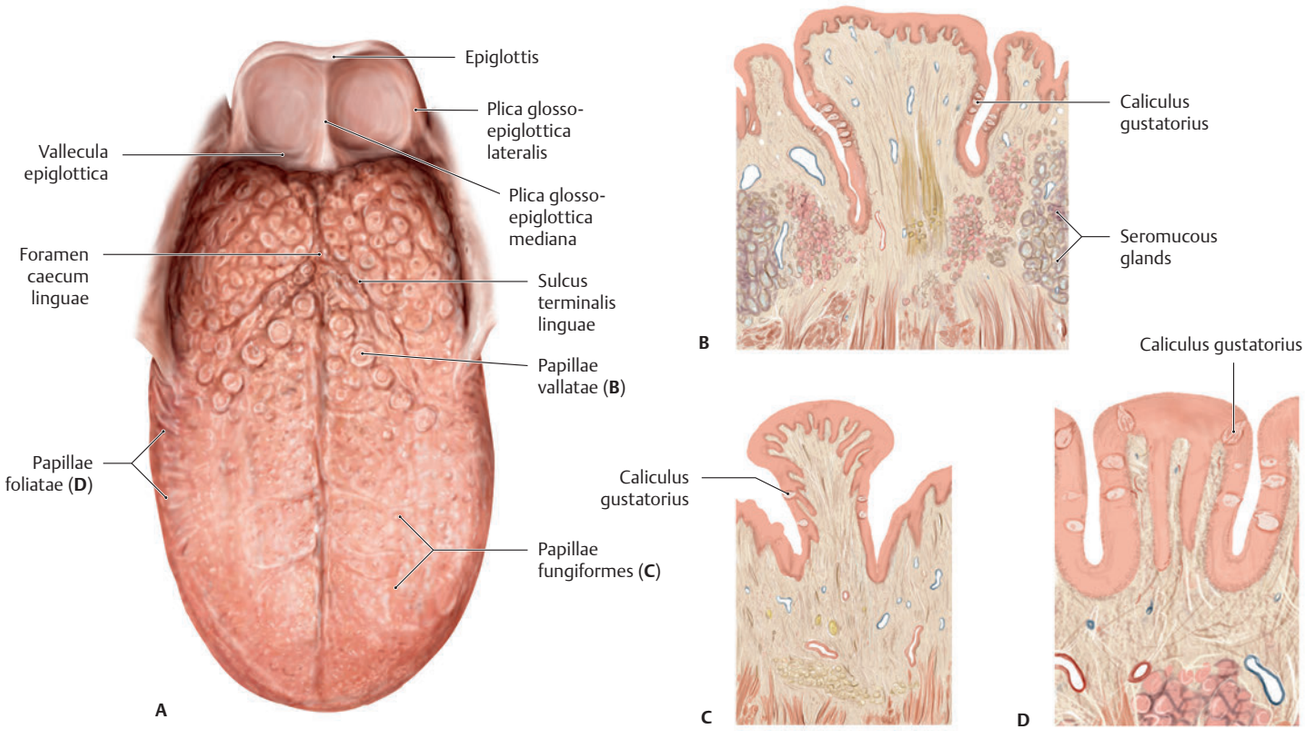


Fig. 8.39 **Organization of the taste receptors in the tongue**
The human tongue contains approximately 4600 caliculi gustatorii in which the secondary sensory cells for taste perception are collected. The caliculi gustatorii are embedded in the epithelium of the tunica mucosa linguae and are located on the surface expansions of the tunica mucosa linguae—the papillae vallatae (principal site, **B**), the papillae fungiformes (**C**), and the papillae foliatae (**D**). Additionally, isolated caliculi gustatorii are located in the mucous membranes of the palatum molle and pharynx. The surrounding serous glands of the tongue (Ebner glands), which are most closely associated with the papillae vallatae, constantly wash the taste buds clean to allow for new tasting. Humans can perceive five basic taste qualities: sweet, sour, salty, bitter, and a fifth "savory" quality, called umami, which is activated by glutamate (a taste enhancer).

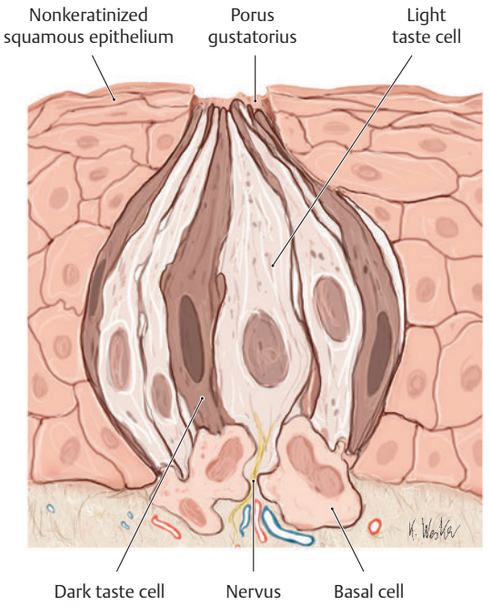


Fig. 8.40 **Microscopic structure of a caliculus gustatorius**
Nerves induce the formation of caliculi gustatorii in the oral mucosa. Axons of nervi craniales VII, IX, and X grow into the oral mucosa from the basal side and induce the epithelium to differentiate into the light and dark taste cells (= modified epithelial cells). Both types of taste cell have microvilli that extend to the porus gustatorius. For sour and salty, the taste cell is stimulated by hydrogen ions and other cations. The other taste qualities are mediated by receptor proteins to which the low-molecular-weight flavored substances bind (details may be found in textbooks of physiology). When the low-molecular-weight flavored substances bind to the receptor proteins, they induce signal transduction that causes the release of glutamate, which excites the peripheral processes of the pseudounipolar neurons of the three cranial nerve ganglia. The taste cells have a life span of approximately 12 days and regenerate from cells at the base of the caliculi gustatorii, which differentiate into new taste cells.

Note: The old notion that particular areas of the tongue are sensitive to specific taste qualities has been found to be false.

Floor of the Cavitas Oris

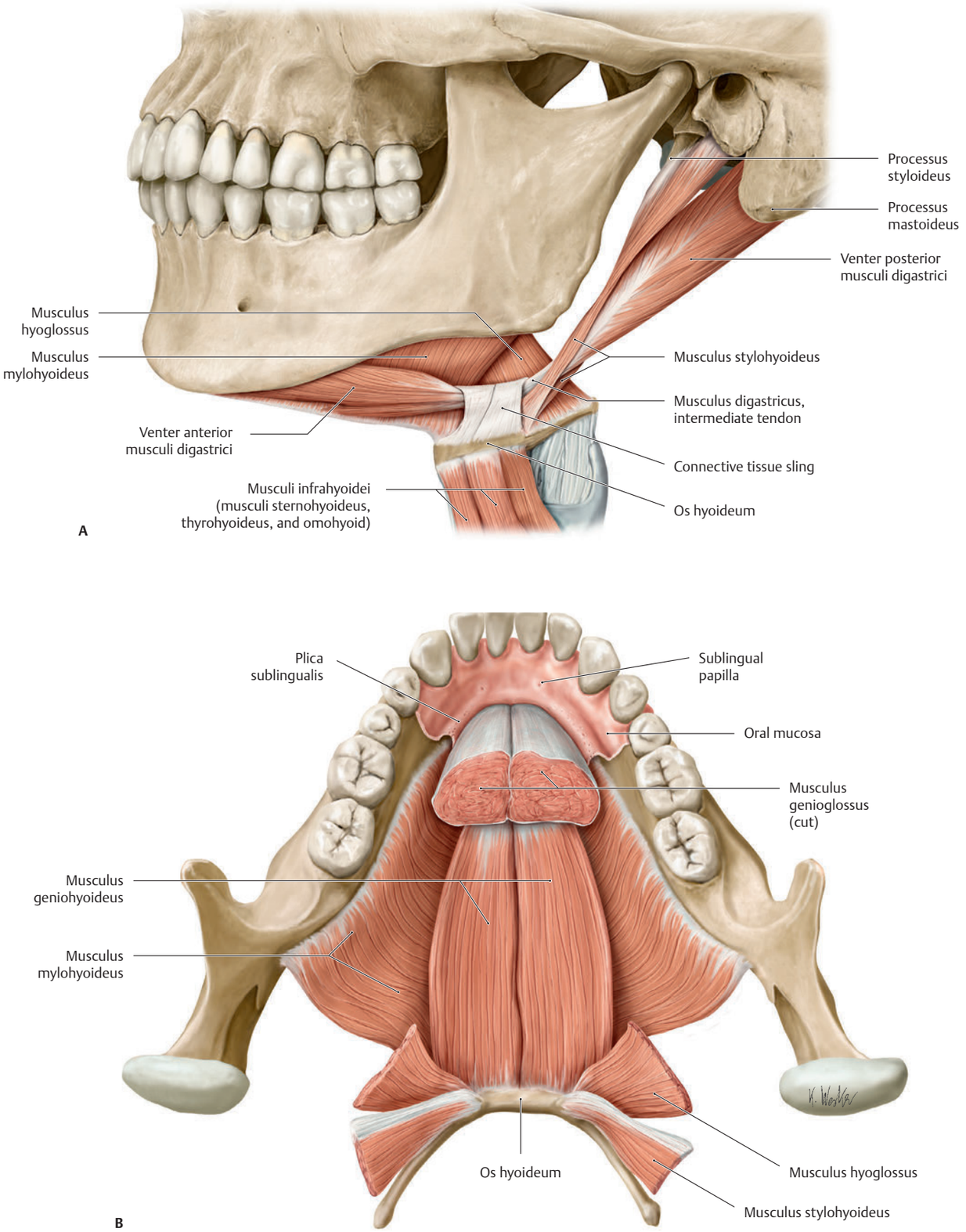


Fig. 8.41 **Muscles of the oral floor**
A Left lateral view. **B** Superior view. Strictly speaking the floor of the cavitas oris is composed only of the musculi mylohyoideus and geniohyoideus. However, other musculi suprahyoidei contribute to this region. The musculi suprahyoidei muscles also play an important role in swallowing (see **Table 8.6**). The musculi suprahyoidei and infrahyoidei attach to the os hyoideum inferiorly and superiorly, respectively. The musculi infrahyoidei depress the os hyoideum during phonation and swallowing. These muscles are discussed in detail on pages 312 and 313.

Table 8.9 **Muscles contributing to the oral floor and surrounding regions**

Muscle		Origin	Insertion		Innervation	Action
Musculus mylohyoideus		Mandibula (linea mylohyoidea)	Corpus ossis hyoidei	Via median tendon of insertion (mylohyoid raphe)	Nervus mylohyoideus. (CN V_3)	Tightens and elevates oral floor; draws os hyoideum forward (during swallowing); assists in opening mandibula and moving it side to side (mastication)
Musculus geniohyoideus		Mandibula (spinae mentales (spinae geni) inferiores)		Directly inserts into os hyoideum	Ramus anterior of C1	Draws os hyoideum forward (during swallowing); assists in opening mandibula
Musculus digastricus*	Venter anterior	Mandibula (fossa digastrica)		Via an intermediate tendon with a fibrous loop	Nervus mylohyoideus (CN V_3)	Elevates os hyoideum (during swallowing); assists in depressing mandibula
	Venter posterior	Os temporale (incisura mastoidea, medial to processus mastoideus)			Nervus facialis (CN VII)	
Musculus stylohyoideus*		Os temporale (processus styloideus)		Via a split tendon	Nervus facialis (CN VII)	

* Not true muscles of the floor of the cavitas oris.

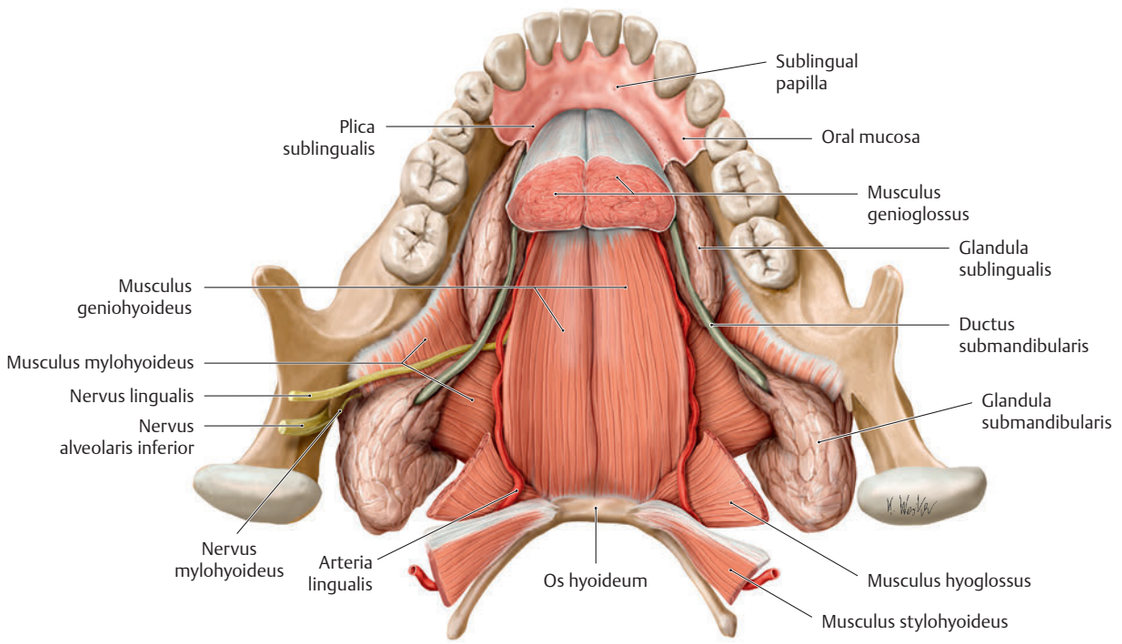


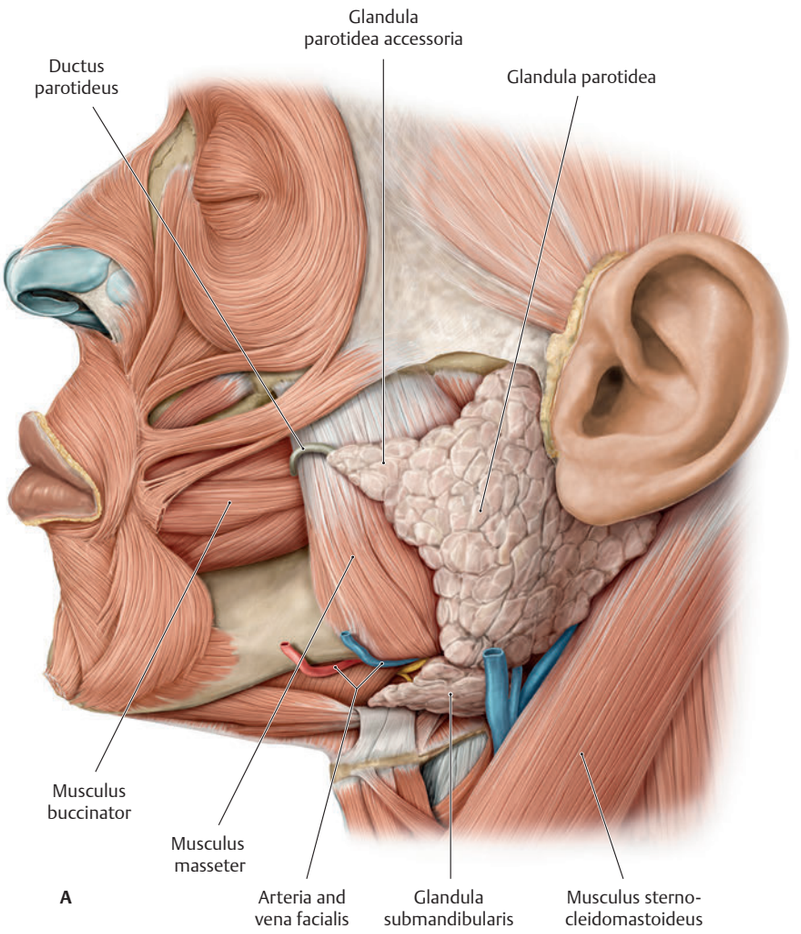
Fig. 8.42 **Topography of the oral floor**
The musculus geniohyoideus is supplied by the arteria sublingualis, a branch of the arteria lingualis, and the arteria submentalis, a branch of the arteria facialis. The arteria sublingualis also supplies the facies inferior linguae and mucosa of the oral floor. The musculus mylohyoideus is supplied by the ramus mylohyoideus of the arteria alveolaris inferior. Venous drainage is via the vena sublingualis, which drains into the vena jugularis interna. Sensory innervation is via the nervus lingualis (CN V_3). Lymphatic drainage is via the nodi submentales and submandibulares.

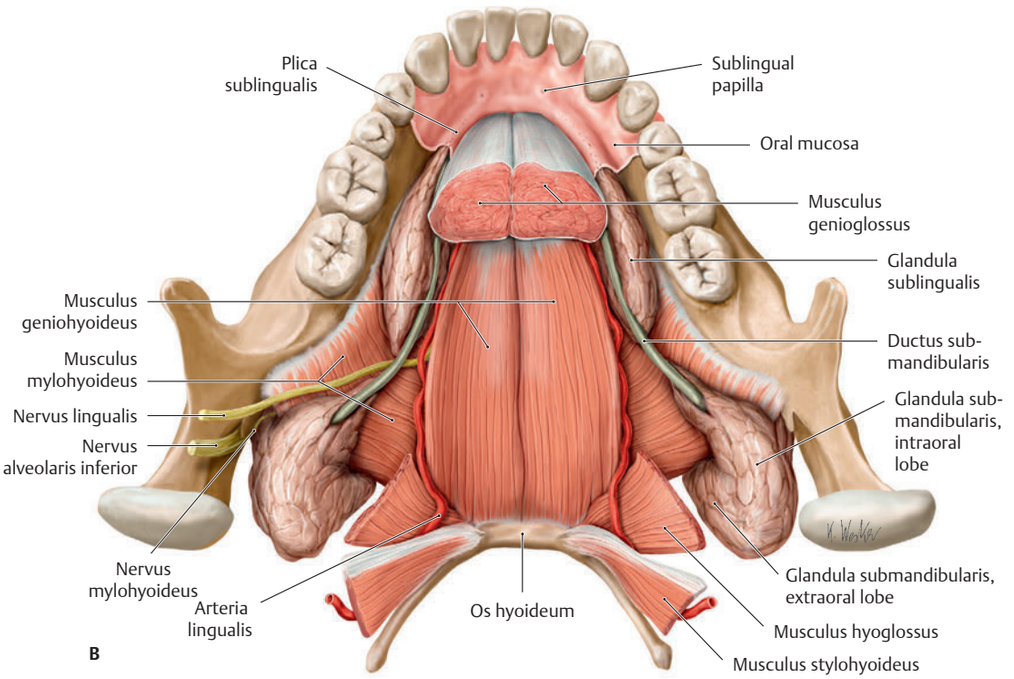
Glandulae Salivariae

Fig. 8.43 **Glandulae salivariae majores**
A Left lateral view. **B** Superior view. There are three glandulae salivariae majores (large, paired): parotidea, submandibularis, and sublingualis. They collectively produce 0.5 to 2.0 liters of saliva per day, excreted into the cavitas oris via excretory ducts. The saliva keeps the oral mucosa moist. It also has digestive and protective functions: saliva contains the starch-splitting enzyme amylase and the bactericidal enzyme lysozyme.

1. **Glandulae parotideae:** Largest of the glandulae salivariae; wedge-shaped but variable; the nervus facialis splits the glandula parotidea into pars superficialis and pars profunda, which are connected by an isthmus; the ductus parotideus arises from the pars profunda and crosses the face superficial to the musculus masseter, pierces the musculus buccinator, and opens into the vestibulum oris opposite the second upper dens molaris (see **Fig 8.1C**); it is a purely serous gland (watery secretions). Malignant tumors of the glandula parotidea may invade surrounding structures directly or indirectly via regional lymph nodes (see **Fig 3.27**). They may also spread systematically through the vascular system.
2. **Glandulae submandibulares:** Second largest of the glandulae salivariae is located in the floor of the cavitas oris, where it wraps around the posterior border of musculus mylohyoideus; the ductus submandibularis opens on to the sublingual papilla behind the lower dentes incisivi; it is a mixed seromucous gland (watery and mucus secretions).
3. **Glandulae sublinguales:** The smallest of the three glandulae salivariae majores; it is located anterior in the floor of the cavitas oris between the oral mucosa and the musculus mylohyoideus; the glandula sublingualis has many smaller excretory ducts that open on the plica sublingualis or into the glandula submandibularis; it is predominantly a mucus-secreting gland (mucoserous).

The glandulae salivariae are a potential site of tumor formation. The majority of such tumors are benign and occur in the pars superficialis of the glandula parotidea. These are pleomorphic adenomas. The tumor cells can lie outside the capsule and so treatment involves surgical excision of the pars superficialis with a margin. Malignant tumors of the glandula parotidea, for example, adenolymphoma, are suspected if there is pain, rapid growth, fixation to surrounding tissues, and involvement of the nervus facialis. Tumors of the glandulae submandibularis, sublingualis, and salivariae minores are more likely to be malignant.





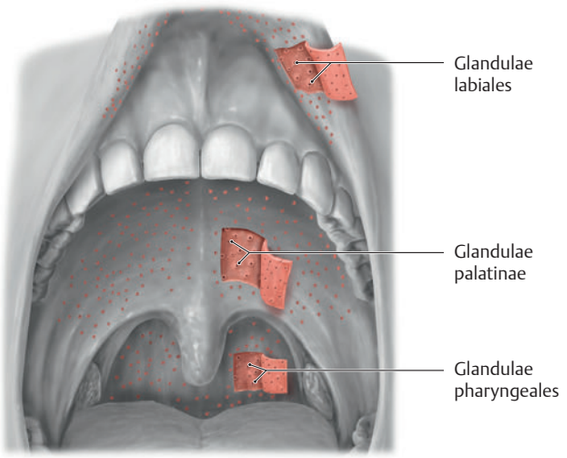


Fig. 8.44 **Glandulae salivariae minores**
In addition to the three major paired glands, 700 to 1000 minor glands secrete saliva into the cavitas oris. They produce only 5 to 8 percent of the total output, but this amount suffices to keep the mouth moist when the glandulae salivariae majores are not functioning.

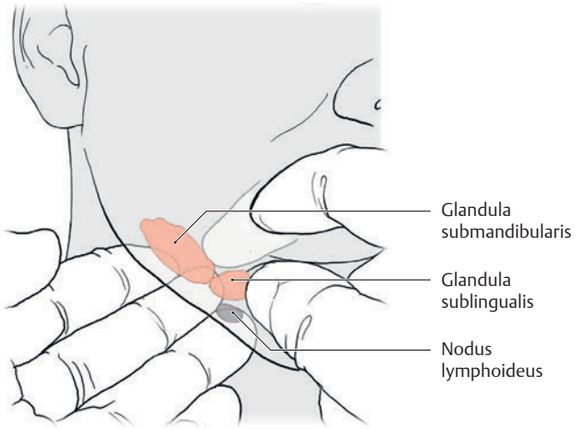


Fig. 8.45 **Bimanual examination of the glandulae salivariae**
The two glandulae salivariae of the mandibula, the glandulae submandibularis and glandula sublingualis, and the adjacent lymph nodes are grouped around the mobile oral floor and therefore must be palpated against resistance. This is done with bimanual examination.

Table 8.10 **Summary of salivary glands**

Gland and duct	Autonomic innervation	Blood supply
Glandula parotidea - Ductus parotideus	Nervus glossopharyngeus (CN IX) — Preganglionic parasympathetic fibers arise from the nucleus salivatorius inferior in the medulla and travel with the nervus petrosus minor (from CN IX) to the ganglion oticum — Postganglionic parasympathetic fibers arise in the ganglion oticum and travel with the nervus auriculotemporalis (of CN V_3) to the glandula parotidea	Glandular branches from the arteria carotis externa and arteria temporalis superficialis
Glandula submandibularis - Ductus submandibularis	Nervus facialis (CN VII) — Preganglionic parasympathetic fibers arise from the nucleus salivatorius superior in the pons. In the canalis nervi facialis it gives rise to two parasympathetic branches: the nervus petrosus major and the chorda tympani o The nervus petrosus major joins the nervus petrosus profundus (sympathetic) to form the nervus canalis pterygoidei. It then travels to the ganglion pterygopalatinum. o The chorda tympani joins the nervus lingualis and travels to the ganglion submandibulare. — Postganglionic parasympathetic fibers from the ganglion pterygopalatinum travel with CN V_2 to the glandulae nasales, palatinae, pharyngeales and labiales superiores. Other postganglionic parasympathetic fibers travel via CN V_2 to the nervus lacrimalis (of CN V_1) to the glandula lacrimalis. — Postganglionic parasympathetic fibers from the ganglion submandibulare travel to the glandulae submandibularis and sublingualis.	Glandular branches of arteria facialis
Glandula sublingualis - Multiple small ducts that open on the plica sublingualis or into the ductus submandibularis		Glandular branches of arteria sublingualis
Glandulae salivariae minores - Small ducts open directly on the mucosa of the cavitas oris and pars oralis pharyngis		
Lymph from the glandula parotidea drains to the superficial and deep cervical nodes; lymph from the glandula submandibularis drains to the nodi cervicales anteriores profundi; lymph from the glandula submandibularis drains to the nodi submandibulares.		

Palata Durum & Molle

The palatum forms the roof of the cavitas oris and the floor of the cavitas nasi. It is divided into a bony palatum durum and a muscular palatum molle.

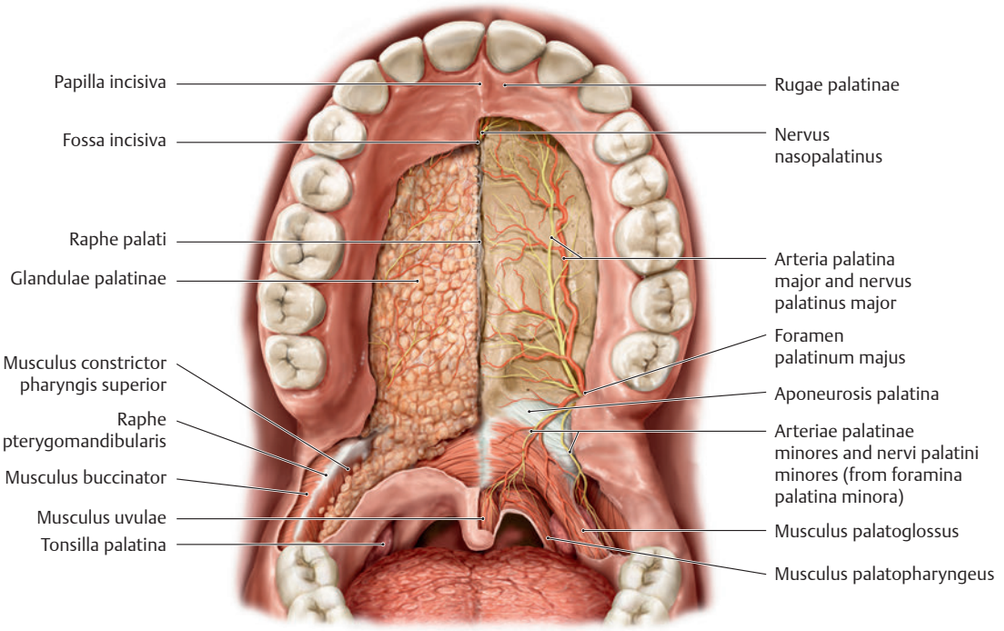


Fig. 8.46 **Palatum durum**
Anterior view. The palatum durum is formed by the processus palatinus of the maxilla and the lamina horizontalis of the os palatinum. It is covered with tough masticatory mucosa, which forms irregular folds anteriorly, known as rugae, which aid in guiding food toward the pharynx. The mucosa is tightly bound to the periosteum of the bones of the palatum durum. The mucosa may become stripped off of the periosteum when local anesthetic solution is introduced into the palatum, which is very painful.
The palatum durum receives its blood supply from the arteria palatina major which arises from the arteria maxillaris. Veins drain to the pteryplexus pterygoideus. Lymph from the palatum durum most commonly drains to the nodi submandibulares or directly to the nodi cervicales profundi superiores. The palatum durum is innervated by branches of the nervus maxillaris division of the nervus trigeminus (CN V_2). The anterior one third of the palatum is innervated by the nervus nasopalatinus, which emerges from the foramen incisivum. The posterior two thirds is innervated by the nervus palatinus major, which emerges from the foramen palatinum majus along with the arteria palatina major (and the nervi palatini minores and arteriae palatinae minores, which innervates and supplies the palatum molle).
This view also shows the raphe pterygomandibularis, which is a ligament formed from the buccopharyngeal fascia. It attaches superiorly to the hamulus pterygoideus and inferiorly to the linea mylohyoidea of the mandibula. The musculus buccinator is attached to the raphe pterygomandibularis anteriorly and the musculus constrictor pharyngis superior. The raphe forms an important landmark for the administration of an inferior alveolar nerve block (see p. 483).

Table 8.11 **Neurovasculature of the palatinum durum**

Blood supply	Venous drainage	Innervation	Lymphatic drainage
Arteria palatina major, arteria sphenopalatina*	Plexus pterygoideus	- Anterior one third: nervus nasopalatinus (from CN V_2) - Posterior two thirds: nervus palatinus major (from CN V_2)	- Nodi submandibulares - Nodi cervicales profundi superiores - Nodi retropharyngeales (rarely)

*Supplies the aspect of the palatum durum that forms the floor of the cavitas nasi.

Table 8.12 **Muscles of the palatum molle**

Muscle	Origin	Insertion	Innervation	Action
Musculus tensor veli palatini	Os sphenoidale (fossa scaphoidea of processus pterygoideus and medial aspect of the spina ossis sphenoidalis; it is connected to the anterolateral membranous wall of the tuba auditiva	Aponeurosis palatina and lamina horizontalis ossis palatini via a tendon that is redirected medially by the hamulus pterygoideus	Nervus pterygoideus medialis (CN V_3)	*Bilaterally:* tenses anterior portion of the palatum molle and flattens its arch, separating the pars nasalis pharyngis from pars oralis pharyngis. Opens tuba auditiva. *Unilaterally:* deviates palatum molle laterally.
Musculus levator veli palatini	Processus vaginalis ossis sphenoidalis and pars petrosa ossis temporalis (via a tendon, anterior to the canalis caroticus); it is connected to the inferior portion of the tuba auditiva	Aponeurosis palatina (the two levators combine to form a muscular sling)	Nervus vagus (CN X) via Plexus pharyngeus	*Bilaterally:* pulls the posterior portion of the palatum molle superoposteriorly, separating the pars nasalis pharyngis from the pars oralis pharyngis.
Musculus uvulae	Os palatinum (spina nasalis posterior) and aponeurosis palatina (superior surface)	Mucosa of the uvula		Pulls the uvula posterosuperiorly, separating the pars nasalis pharyngis from the pars oralis pharyngis.
Musculus palatoglossus (arcus palatoglossush)	Aponeurosis palatina (oral surface)	Lateral tongue to dorsum linguae or intrinsic musculus transversus linguae		*Bilaterally:* pulls the root of the tongue superiorly narrowing the isthmus faucium, separating the cavitas oris from the pars oralis pharyngis.

Sensory innervation: nervi palatini minores (from CN V_2)
Blood supply: arteriae palatinae minores (from arteria maxillaris), arteria palatina ascendens (from arteria facialis), palatine branch of the arteria pharyngea ascendens (from arteria carotis externa)
Venous drainage: plexus pterygoideus
Lymphatic drainage: nodi submandibularis, nodi retropharyngeales

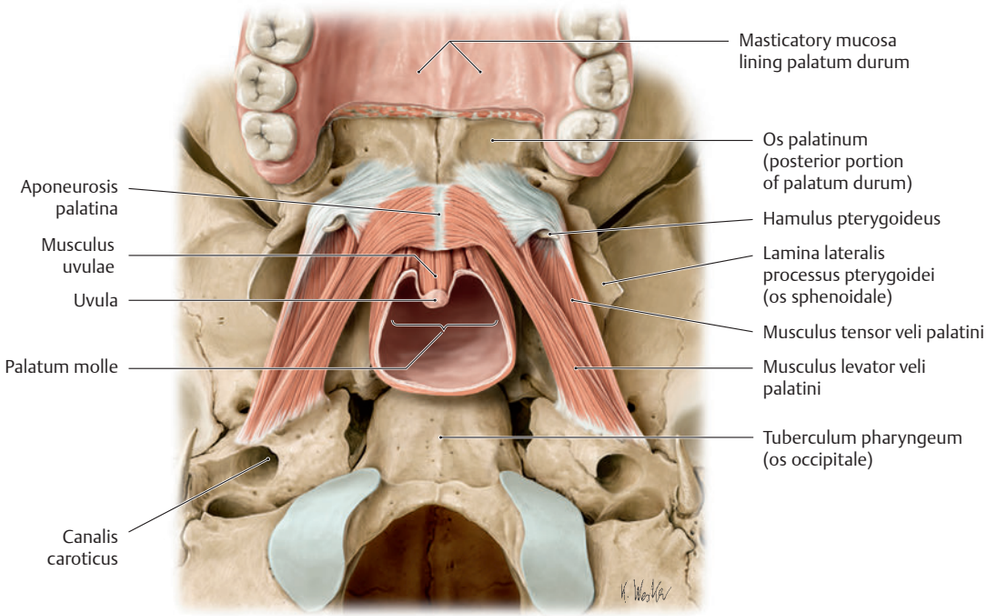


Fig. 8.47 **Muscles of the palatum molle and tuba auditiva**
Inferior view. The palatum molle is the aponeurotic and muscular region hanging from the palatum durum at the posterior portion of the cavitas oris. It separates the pars oralis pharyngis from the pars nasalis pharyngis, particularly during swallowing when it is tensed. The musculus palatoglossus restricts the communication between the cavitas oris and pars oralis pharyngis. The musculus tensor veli palatini has a significant role in keeping open the tuba auditiva.

Pharynx: Divisions & Contents

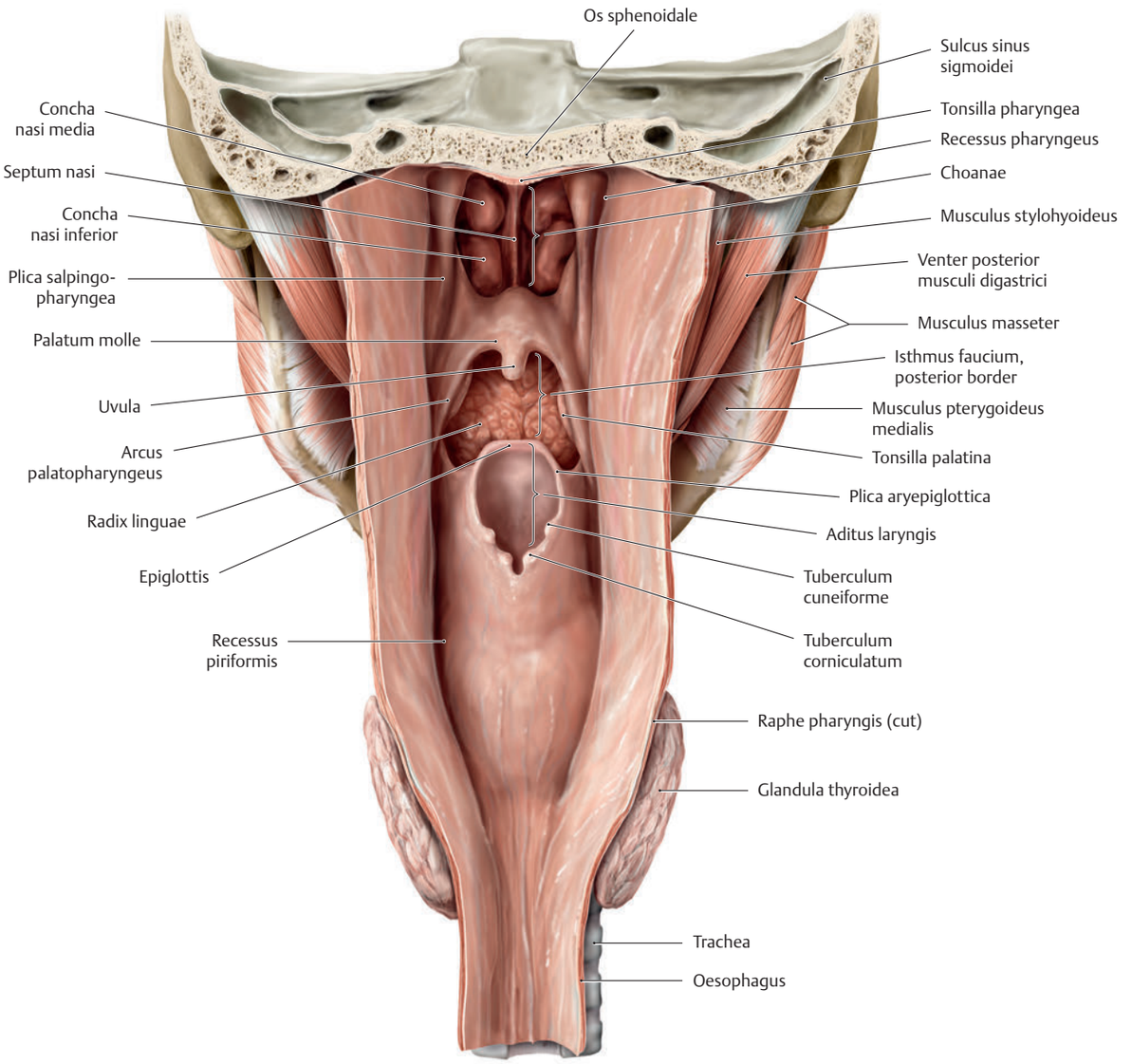


Fig. 8.48 **Pharyngeal mucosa and musculature**
Posterior view. **A** Mucosal lining. **B** Internal musculature. The muscular posterior wall of the pharynx has been divided along the midline (raphe pharyngis) and spread open to demonstrate its mucosal anatomy.

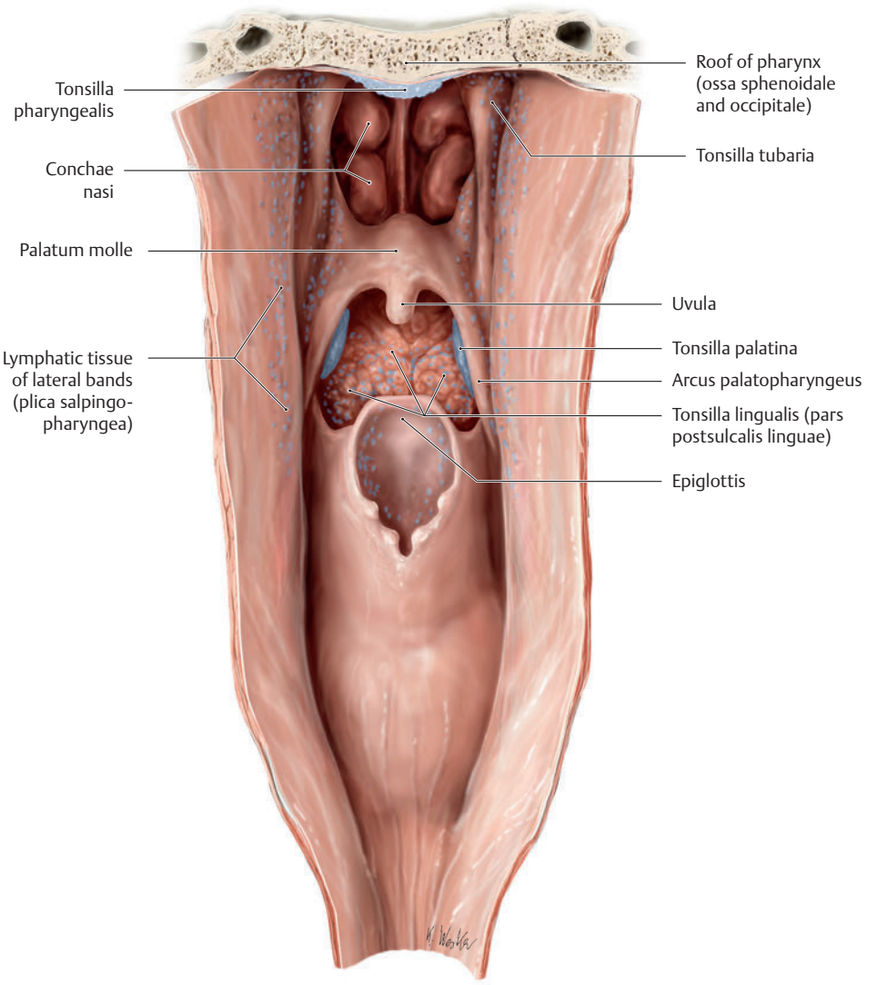
Table 8.13 **Levels of the pharynx**

The anterior portion of the muscular pharyngeal tube communicates with three cavities (nasal, oral, and laryngeal). The three anterior openings divide the pharynx into three parts with corresponding vertebral levels.

Region	Level	Description	Communications	
Pars nasalis pharyngis (Epipharynx)	C1	Upper portion, lying between the roof (formed by ossa sphenoidale and occipitale) and the palatum molle	Cavitas nasi	Via choanae
			Cavitas tympani	Via tuba auditiva
Pars oralis pharyngis (Mesopharynx)	C2–C3	Middle portion, lying between the uvula and the epiglottis	Cavitas oris	Via isthmus faucium (formed by the arcus palatoglossus)
Pars laryngea pharyngis (Hypopharynx)	C4–C6	Lower portion, lying between the epiglottis and the inferior border of the cartilago cricoidea	Larynx	Via aditus laryngis
			Oesophagus	Via musculus cricopharyngeus (pars cricopharyngea musculi constrictoris pharyngis inferioris)

***Fig. 8.49* Waldeyer's ring**
Posterior view of the opened pharynx. Waldeyer's ring is composed of immunocompetent lymphatic tissue (tonsils and lymph follicles). The tonsils are "immunological sentinels" surrounding the passageways from the mouth and cavitas nasi to the pharynx. The lymph follicles are distributed over all of the epithelium, showing marked regional variations. Waldeyer's ring consists of the following structures:

- Unpaired tonsilla pharyngealis on the roof of the pharynx
- Paired tonsillae palatinae in the pars oralis pharyngis between the anterior and posterior pillars (the arcus palatoglossus and the arcus palatopharyngeus)
- Tonsilla lingualis, the lymph nodes embedded in the postsulcal portion of the tongue
- Paired tonsillae tubariae, which may be thought of as lateral extensions of the tonsilla pharyngealis
- Paired lateral bands in the plica salpingopharyngea



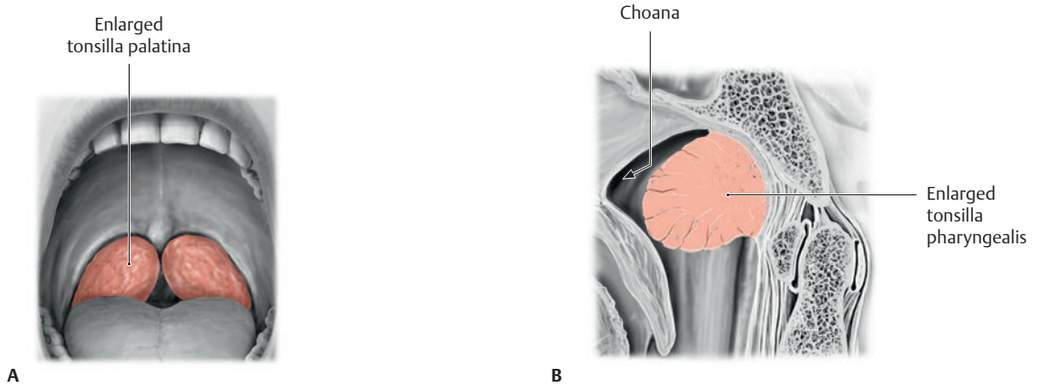


***Fig. 8.50* Abnormal enlargement of the tonsillae pharyngeales and palatinae**
A Anterior view of the cavitas oris. **B** Sagittal section through the roof of the pharynx.
A Severe enlargement of the tonsilla palatina (due to viral or bacterial infection, as in tonsillitis) may significantly narrow the outlet of the cavitas oris, causing difficulty in swallowing (dysphagia). Tonsillectomy, surgical removal of the tonsilla palatina from the tonsillar bed along with its accompanying fascia, may damage the nervus glossopharyngeus (CN IX), which lies on the lateral wall of the pharynx. This could result in loss of sensation and taste from the posterior one third of the tongue.
B An enlargement of the tonsilla pharyngealis is very common in preschool-aged children. Chronic recurrent nasopharyngeal infections at that age often evoke a heightened immune response in the lymphatic tissue, causing "adenoids" or "polyps." The enlarged tonsilla pharyngealis blocks the choanae, obstructing the nasal airway and forcing the child to breathe through the mouth. Because the mouth is constantly open during respiration at rest, an experienced examiner can quickly diagnose the adenoidal condition by visual inspection.

Muscles of the Pharynx (I)

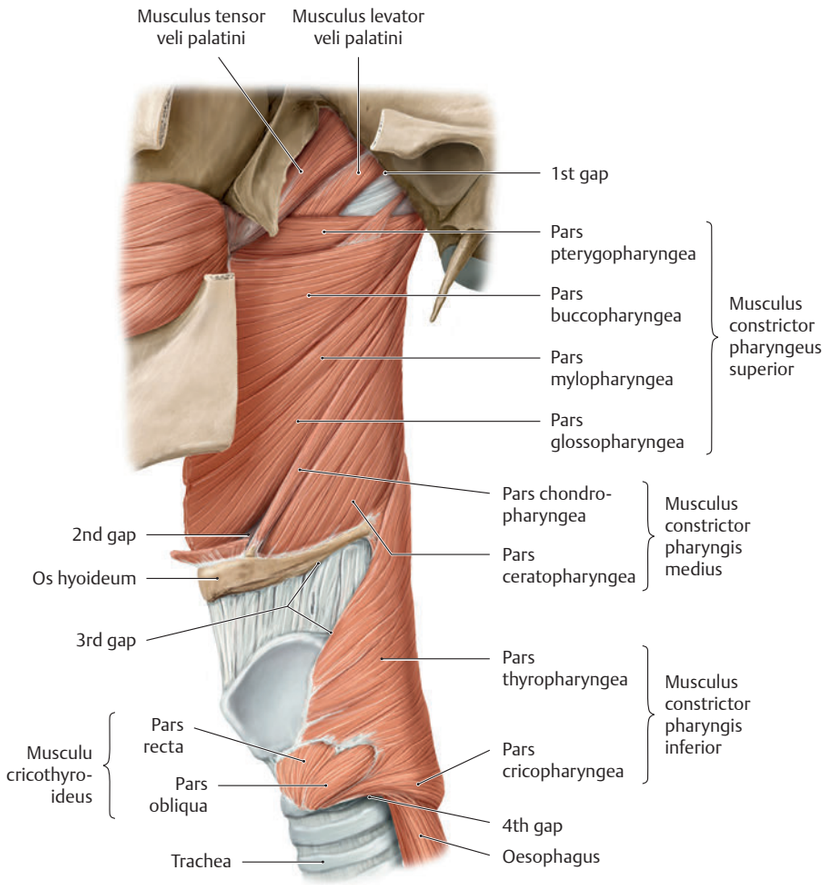


Fig. 8.51 **Pharyngeal constrictors**
Left lateral view.

Table 8.14 **Pharyngeal gaps**

Gap	Transmitted structures
1st gap	Tuba auditiva
	Musculus levator veli palatini
2nd gap	Musculus stylopharyngeus (inserts on larynx)
	Nervus glossopharyngeus (CN IX)
3rd gap	Ramus internus nervi laryngei superioris
	Arteria and vena laryngea superior
4th gap	Nervus laryngeus recurrens
	Arteria laryngea inferior

Table 8.15 **Pharyngeal constrictors**

Muscle		Origin	Insertion	Innervation	Action
Musculus constrictor pharyngis superior	Pars pterygopharyngea	Hamulus pterygoideus (occasionally to the lamina media processus pterygoidei)	Os occipitale (tuberculum pharyngeum partis basilaris, via median raphe pharyngis)	Nervus vagus (CN X) via plexus pharyngeus	Constricts the upper pharynx
	Pars buccopharyngea	Raphe pterygomandibularis			
	Pars mylopharyngea	Linea mylohyoidea mandibulae			
	Pars glossopharyngea	Lateral tongue			
Musculus constrictor pharyngis medius	Pars chondropharyngea	Cornu minus ossis hyoidei and ligamentum stylohyoideum			Constricts the middle pharynx
	Pars ceratopharyngea	Cornu majus ossis hyoidei			
Musculus constrictor pharyngis inferior	Pars thyropharyngea	Lamina cartilaginis thyroideae and cornu inferius ossis hyoidei			Constricts the lower pharynx
	Pars cricopharyngea	Cartilago cricoidea (lateral margin)		Nervus laryngeus recurrens (CN X) and/or ramus externus nervi laryngei superioris	Sphincter at intersection of pars laryngea pharyngis and oesophagus

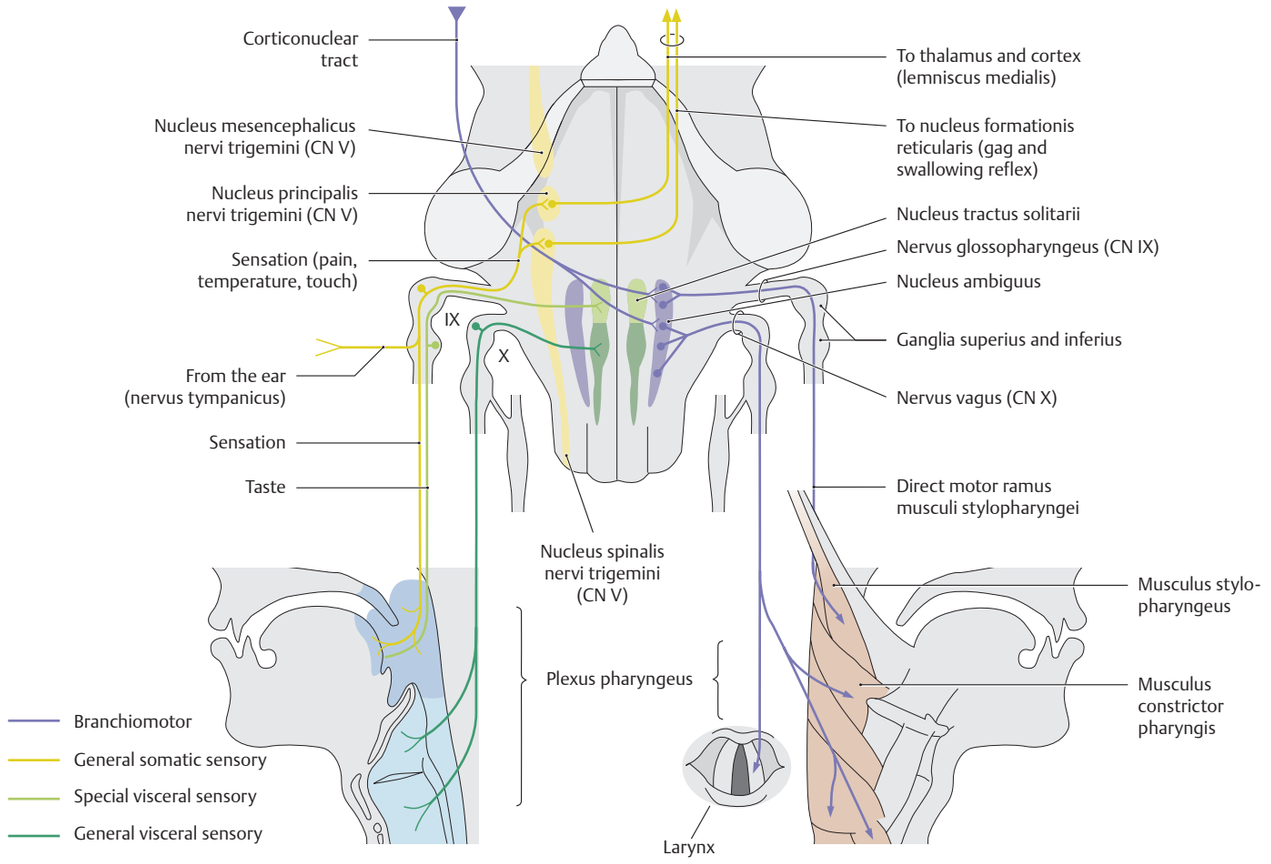


Fig. 8.52 **Plexus pharyngeus**
The pharynx receives sensory and motor innervation via the plexus pharyngeus, formed by both the nervi glossopharyngeus (CN IX) and vagus (CN X), along with postganglionic sympathetic fibers from the ganglion cervicale superius. *Note:* Only the nervus vagus contributes motor fibers to the plexus (the musculus stylopharyngeus is supplied directly by CN IX).

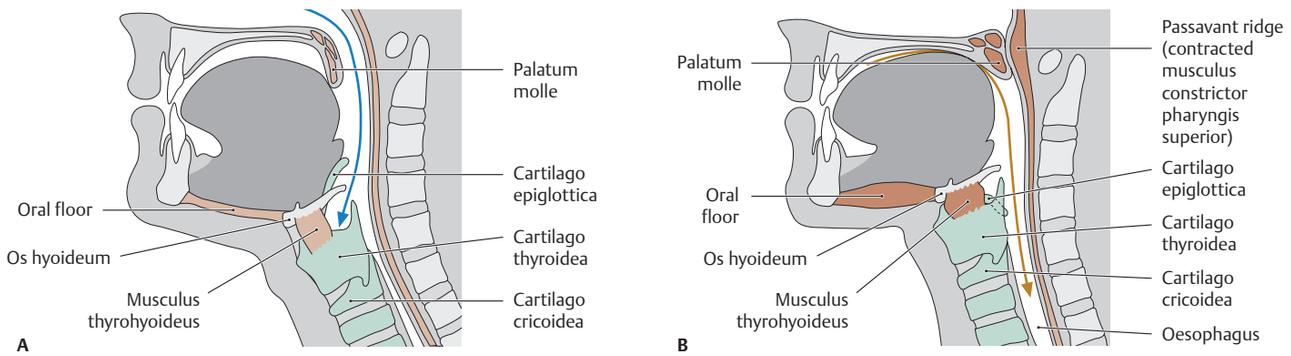


Fig. 8.53 **Swallowing**
The larynx, part of the airway, is located at the inlet to the digestive tract (**A**). During swallowing (**B**), the airway must be occluded to keep food from entering the larynx and the trachea (preventing choking). Swallowing consists of three phases:

1. Oral stage (voluntary initiation): The lingual muscles move the food bolus to the isthmus faucium, which first expands and then contracts.
2. Pharyngeal stage (reflex closure of airway): The longitudinal pharyngeal muscles elevate the larynx. The lower airway (aditus laryngis) is covered by the epiglottis. Meanwhile, the palatum molle is tensed and elevated against the posterior pharyngeal wall, sealing off the upper airway.
3. Pharyngoesophageal stage (reflex transport): The constrictors move the food bolus to the stomach.

Muscles of the Pharynx (II)

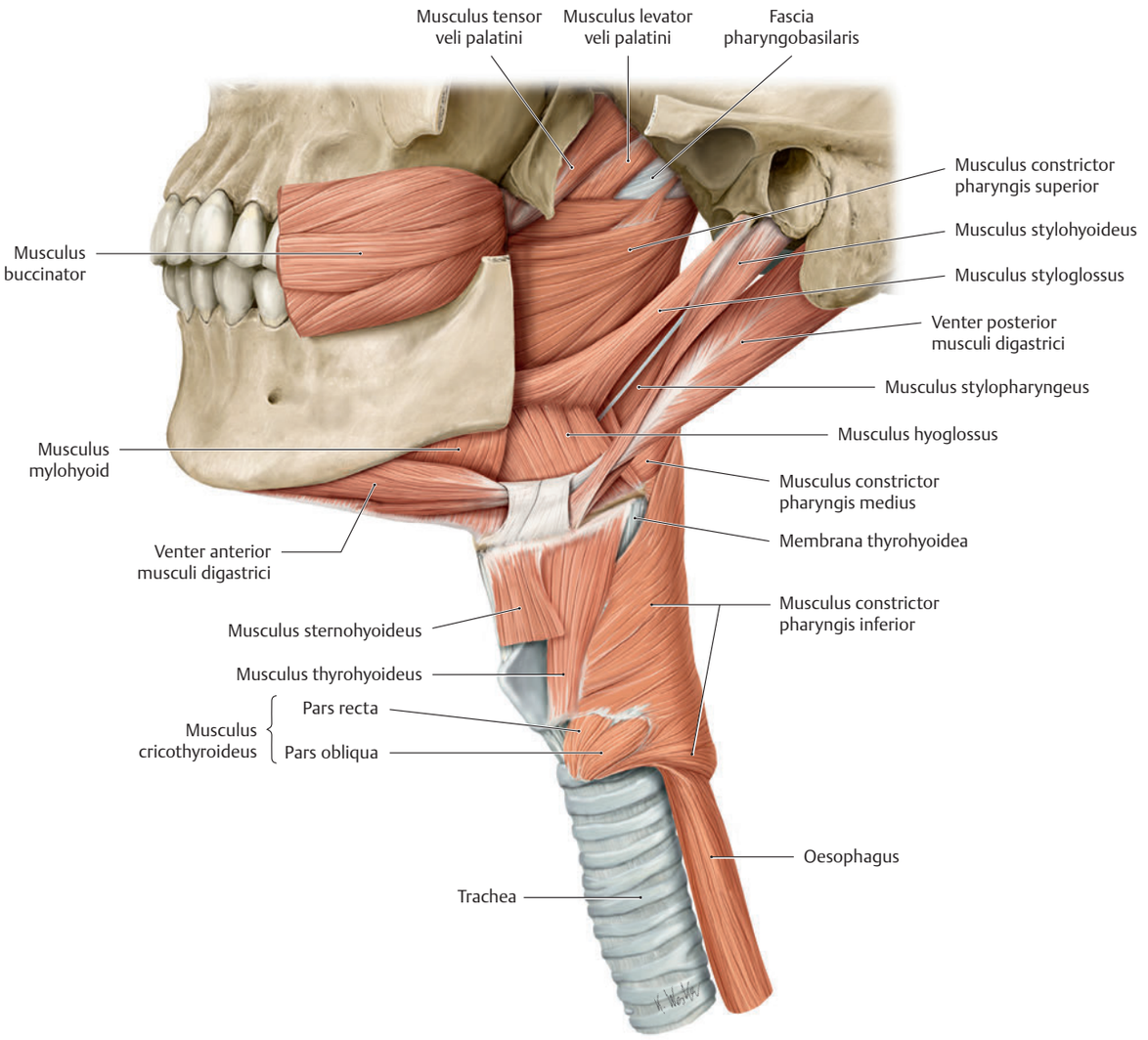


Fig. 8.54 **Pharyngeal musculature**
Left lateral view.

Table 8.16 **Pharyngeal elevators**

Muscle	Origin	Insertion	Innervation	Action
Musculus palatopharyngeus (arcus palatopharyngeus)	Aponeurosis palatina (superior surface) and posterior border of os palatinum	Cartilago thyroidea (posterior border) or lateral pharynx	Nervus vagus (CN X) via plexus pharyngeus	*Bilaterally:* Elevates the pharynx anteromedially.
Musculus salpingopharyngeus	Pars cartilaginea tubae auditivae (inferior surface)	Along plica salpingopharyngea to musculus palatopharyngeus		*Bilaterally:* Elevates the pharynx; may also open tuba auditiva.
Musculus stylopharyngeus	Processus styloideus (medial surface of base)	Lateral pharynx, mixing with pharyngeal constrictors, musculus palatopharyngeus, and cartilago thyroidea (posterior border)	Nervus glossopharyngeus (CN IX)	*Bilaterally:* Elevates the pharynx and larynx.

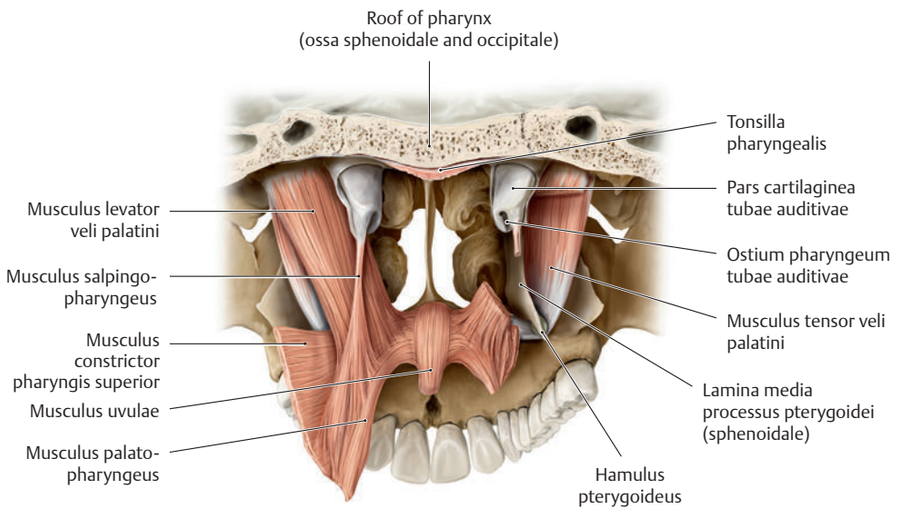


Fig. 8.55 **Muscles of the palatum molle and pharyngeal elevators**
Posterior view.

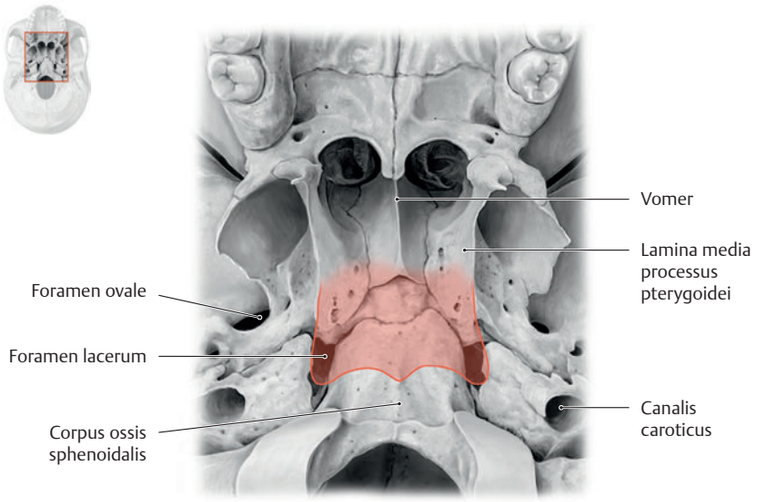


Fig. 8.56 **Fascia pharyngobasilaris at the base of the skull**
Inferior view. The pharyngeal musculature arises from the base of the skull by a thick sheet of connective tissue, the fascia pharyngobasilaris (its outline is shown in red). The fascia pharyngobasilaris ensures that the pars nasalis pharyngis is always open.

Muscles of the Pharynx (III) & Innervation

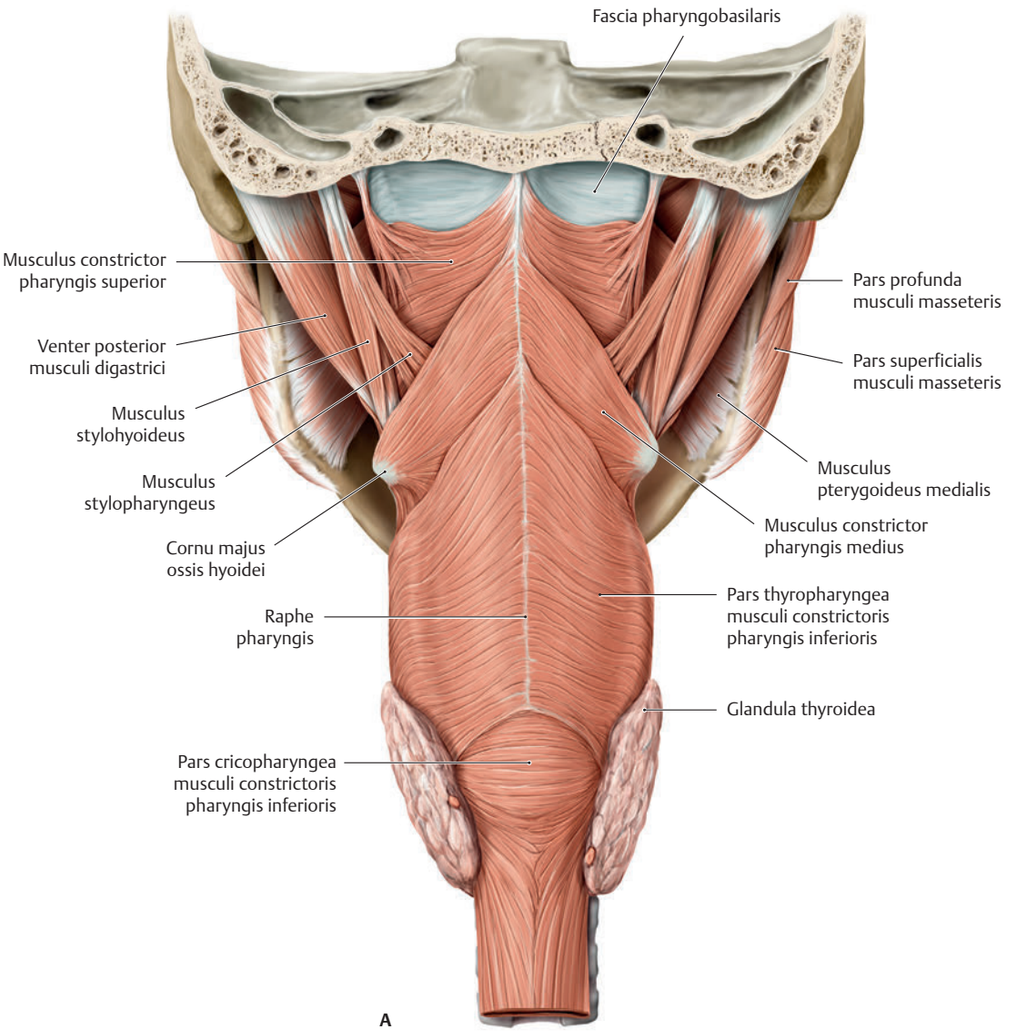
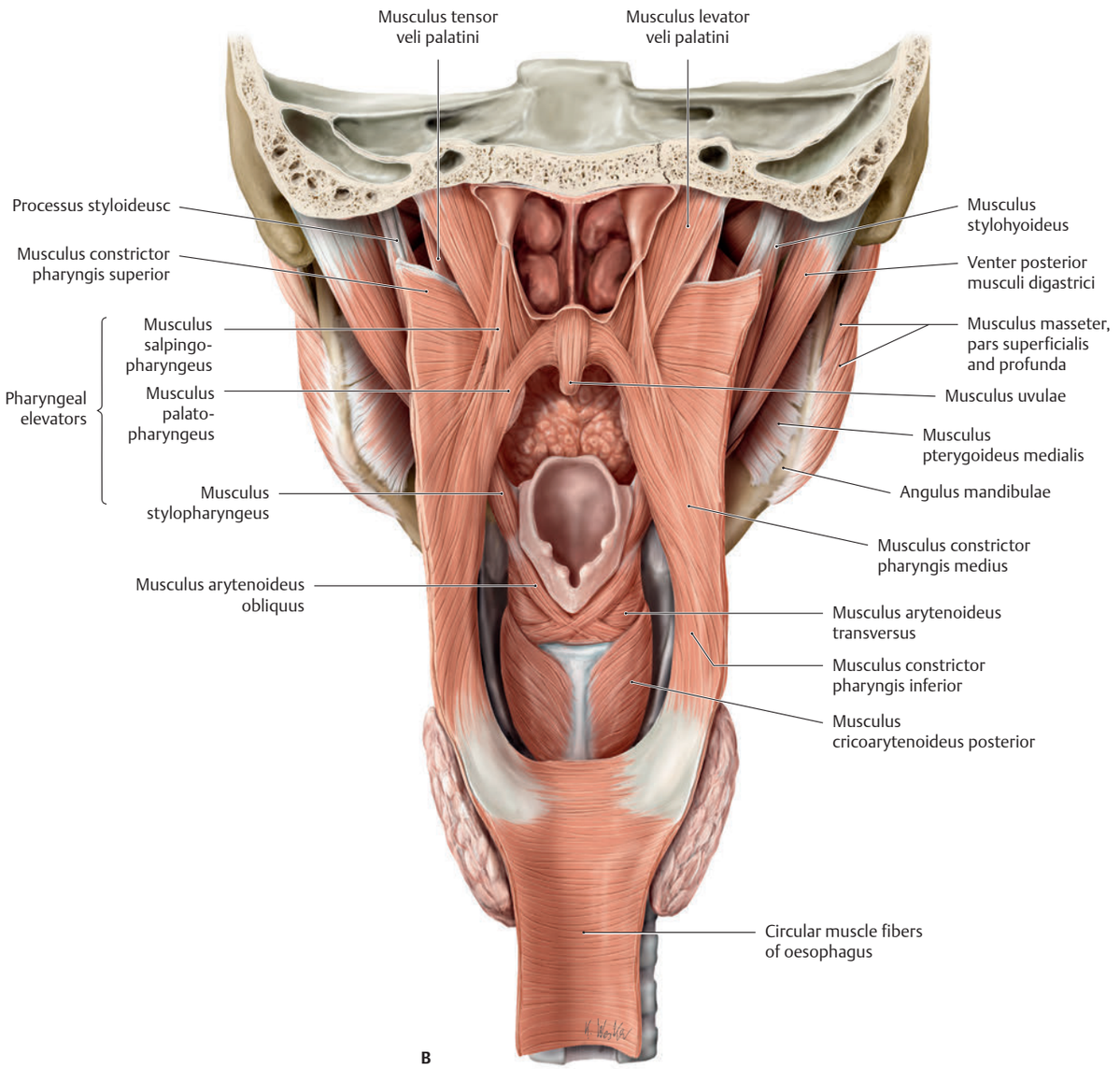


Fig. 8.57 **Pharyngeal musculature**
A Posterior view. **B** Internal musculature. The pharynx is a muscular tube composed of three *pharyngeal constrictors* (**Table 8.15**) and three *pharyngeal elevators* (**Table 8.16**).


Musculus tensor veli palatini
Musculus levator veli palatini
Processus styloideusc
Musculus constrictor pharyngis superior
Pharyngeal elevators
Musculus salpingo-pharyngeus
Musculus palato-pharyngeus
Musculus stylopharyngeus
Musculus arytenoideus obliquus
Musculus stylohyoideus
Venter posterior musculi digastrici
Musculus masseter, pars superficialis and profunda
Musculus uvulae
Musculus pterygoideus medialis
Angulus mandibulae
Musculus constrictor pharyngis medius
Musculus arytenoideus transversus
Musculus constrictor pharyngis inferior
Musculus cricoarytenoideus posterior
Circular muscle fibers of oesophagus

B

Neurovascular Topography of the Pharynx

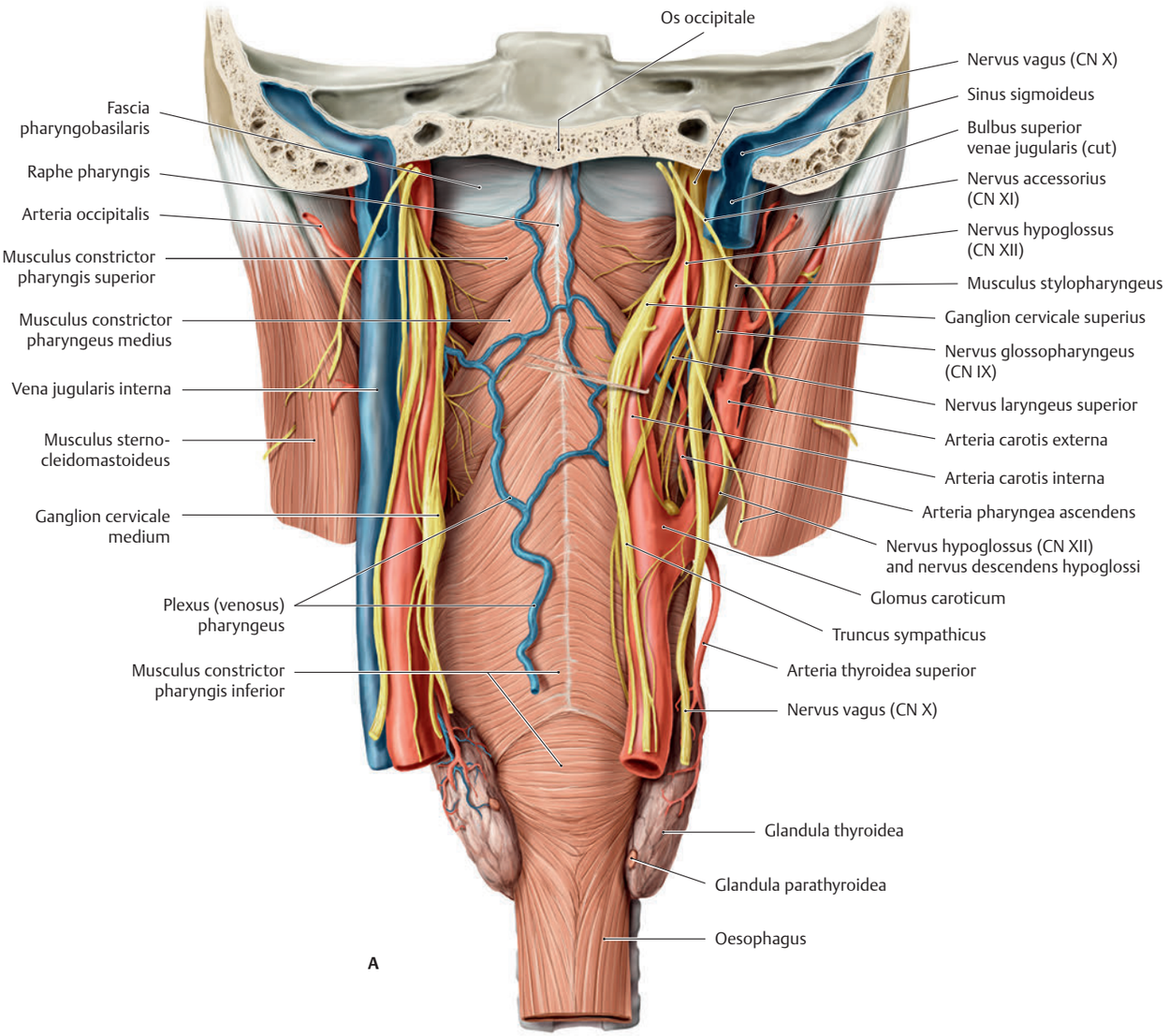
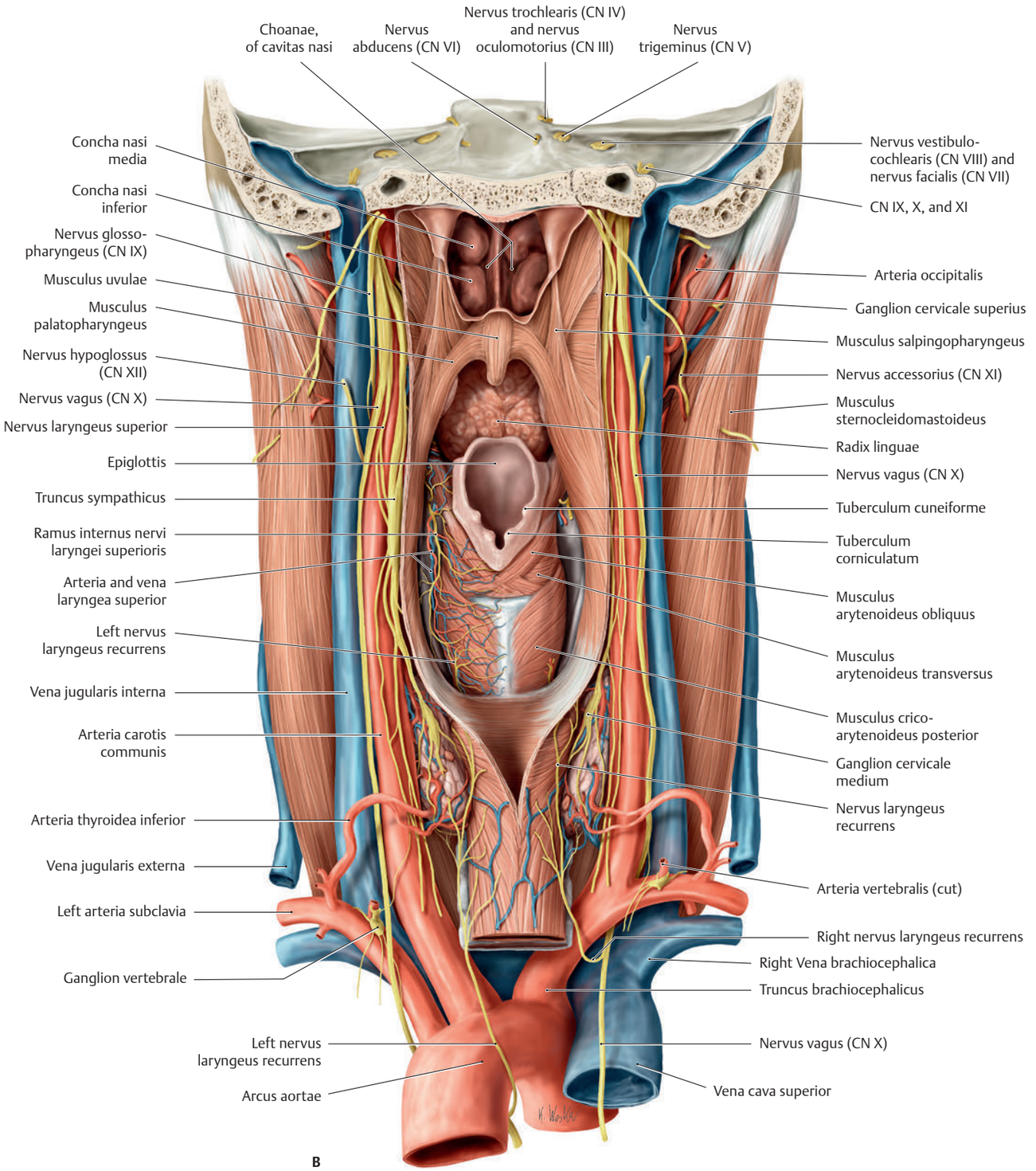


Fig. 8.58 **Neurovascular topography of the pharynx**
A Posterior view with fascia removed. **B** Posterior view with pharynx opened along raphe pharyngis.

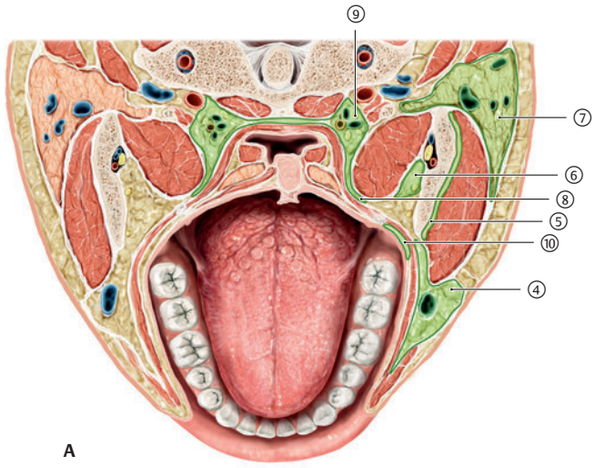
The majority of the pharyngeal muscles are supplied by motor fibers from the plexus pharyngeus nervi vagi. Exceptions are the musculus stylopharyngeus, which is innervated by a motor branch from nervus glossopharyngeus (CN IX), and the pars cricopharyngea musculi constrictoris pharyngis inferior, which is generally supplied by the nervus laryngeus recurrens and/or the ramus externus nervi laryngei superioris (occasionally by the plexus pharyngeus). The plexus pharyngeus is composed of both motor and sensory fibers. The nervi glossopharyngeus and vagus (CN IX and CN X, respectively) both contribute sensory fibers to the nerve plexus; only the nervus vagus distributes motor fibers to the plexus pharyngeus (some of these fibers may be considered to have originated from the spinal nervus accessorius [CN XI]). Regardless of origin, they are distributed by the nervus vagus. The plexus also receives autonomic fibers from the cervical sympathetic chain.

Arteries in the region of the pharynx, primarily branches of the arteria carotis externa, contribute to the vascular supply of the pharyngeal structures. The venous drainage of the posterior wall of the pharynx is primarily into the plexus (venosus) pharyngeus, which in turn drains into the vena jugularis interna.


Choanae, of cavitas nasi
Nervus abducens (CN VI)
Nervus trochlearis (CN IV) and nervus oculomotorius (CN III)
Nervus trigeminus (CN V)
Concha nasi media
Concha nasi inferior
Nervus glosso-pharyngeus (CN IX)
Musculus uvulae
Musculus palatopharyngeus
Nervus hypoglossus (CN XII)
Nervus vagus (CN X)
Nervus laryngeus superior
Epiglottis
Truncus sympathicus
Ramus internus nervi laryngei superioris
Arteria and vena laryngea superior
Left nervus laryngeus recurrens
Vena jugularis interna
Arteria carotis communis
Arteria thyroidea inferior
Vena jugularis externa
Left arteria subclavia
Ganglion vertebrale
Left nervus laryngeus recurrens
Arcus aortae
Nervus vestibulo-cochlearis (CN VIII) and nervus facialis (CN VII)
CN IX, X, and XI
Arteria occipitalis
Ganglion cervicale superius
Musculus salpingopharyngeus
Nervus accessorius (CN XI)
Musculus sternocleidomastoideus
Radix linguae
Nervus vagus (CN X)
Tuberculum cuneiforme
Tuberculum corniculatum
Musculus arytenoideus obliquus
Musculus arytenoideus transversus
Musculus crico-arytenoideus posterior
Ganglion cervicale medium
Nervus laryngeus recurrens
Arteria vertebralis (cut)
Right nervus laryngeus recurrens
Right Vena brachiocephalica
Truncus brachiocephalicus
Nervus vagus (CN X)
Vena cava superior

B

Potential Tissue Spaces in the Head & Spread of Dental Infections



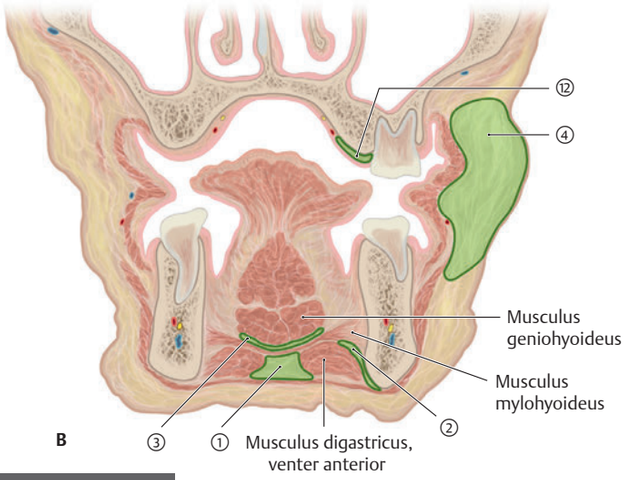
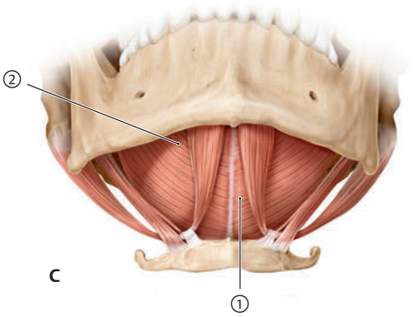


Table 8.17 **Potential tissue spaces of the head**

Potential tissue space	Is located	Communicates with
Around mandibula		
① Submental space	Below inferior border of mandibula and beneath musculus myohyoideus, at midline of neck (corresponds to trigonum submentale region)	Submandibular spaces on both sides
② Submandibular space	Below inferior border of mandibula and beneath musculus myohyoideus, bounded by ventri anterior and posterior of musculus digastricus	Sublingual, submental, and parapharyngeal spaces
③ Sublingual space	Above musculus myohyoideus and below the tongue	Submandibular and parapharyngeal spaces
④ Buccal space	In cheek, lateral to musculus buccinator	Canine, submasseteric, and parapharyngeal spaces, and sinus cavernosus
⑤ Submasseteric space	Between lateral surface of ramus mandibulae and musculus masseter	Parapharyngeal spaces
⑥ Pterygomandibular space	Between medial surface of ramus mandibulae and the musculus pterygoideus medialis	Buccal, infratemporal, parotid, submasseteric, parapharyngeal, and peritonsillar spaces
⑦ Parotid space	Behind ramus mandibulae, in and around glandula parotidea	Parapharyngeal then retropharyngeal spaces with potential spread to mediastinum
⑧ Parapharyngeal space	Lateral to the pharynx in the suprahyoid region of neck	Continuous with retropharyngeal space
⑨ Retropharyngeal space	• Between fascia buccopharyngealis anteriorly and lamina prevertebralis posteriorly • Extends from base of skull to retrovisceral space in infrahyoid region of neck	Parapharyngeal, submandibular, sublingual, submasseteric, and peritonsillar spaces, and mediastinum
⑩ Peritonsillar	Around tonsillae palatinae between pillars of fauces, bounded by the medial surface of the musculus constrictor pharyngis superior	Submandibular and sublingual spaces
Around maxilla		
⑪ Canine space	Between musculus levator anguli oris and musculus levator labii superioris	Sinus cavernosus
⑫ Palatal space	Between periosteum and mucosa of hard palatum durum mucosa	None
⑬ Infratemporal space	Within fossa infratemporalis	Pterygomandibular and buccal spaces, sinus cavernosus (via plexus pterygoideus)



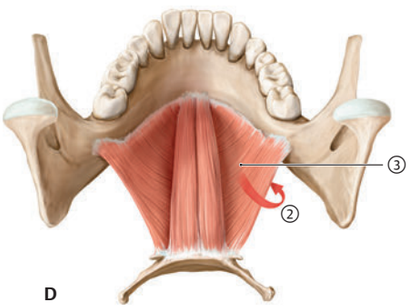


Fig. 8.59 **Potential tissue spaces in the head**

A Transverse section at the level of the occlusal plane of the mandibular teeth, superior view. **B** Coronal section through the molar region of the cavitas oris. **C** Floor of the mouth, inferior oblique view. **D** Floor of the mouth, superior view.

Potential tissue spaces in the head become true spaces when they are infiltrated by bacterial products of infection, such as hyaluronidase, which break down the connective tissue in these spaces. These spaces, defined by the positions of bones, muscles, and fascia, initially confine an infection, but because of communication between spaces, infections can travel.

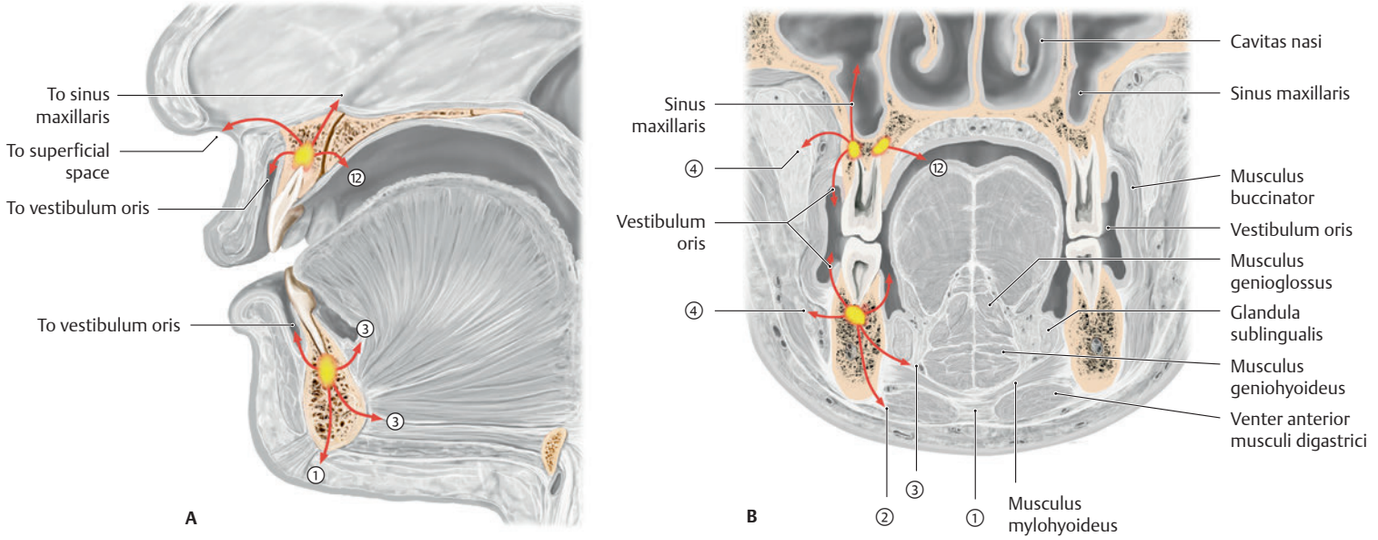


Table 8.18 **Route of infection from dental source**

Source of infection	Route of infection	Symptoms
Mandibular anterior teeth	Below attachment of musculus mylohyoideus to ① submental space	Swelling under chin
Mandibular dentes molares	Below attachment of musculus mylohyoideus to ② submandibular space	Swelling in submandibular region, resulting in difficulty swallowing (dysphagia), difficulty breathing (dyspnea), and difficulty articulating speech (dysarthria), and neck pain and swelling, drooling, earache, and malaise (=Ludwig angina)
Mandibular dentes premolares/ molares	Below musculus geniohyoideus and above musculus mylohyoideus to ③ sublingual space	Swelling in floor of mouth, resulting in elevated tongue and difficulty speaking and swallowing
Maxillary or mandibular dentes premolares/ molares	Above (for maxillary teeth) or below (for mandibular teeth) the attachment of musculi buccinatores to ④ buccal space	Extensive swelling of cheek, which may extend to the upper lip or eye
Mandibular third dentes molares	Posterolaterally between lateral aspect of ramus mandibulae and musculus masseter to ⑤ submassateric space	Pain, trismus*, swelling of tonsillar pillars
	Posteriorly between the medial aspect of ramus mandibulae and musculus pterygoideus medialis to ⑥ pterygomandibular space	Trismus*, intraoral swelling along the medial aspect of the mandibula
Maxillary or mandibular dentes molares	Posteromedially to enter ⑧ parapharyngeal space then to ⑨ retropharyngeal space	Pain, trismus*, swollen palatum molle with deviated uvula, difficulty swallowing, difficulty breathing (airway obstruction could be life-threatening)
Maxillary anterior teeth (usually dentes canini)	Above origin of musculus levator anguli oris to ⑪ canine space	Swelling along lateral border of nose, which may extend to periorbital region; eyelids may become swollen shut
Maxillary dentes premolares or molares	From the radix palatinalis into ⑫ palatal space	Small, painful swelling of palatum
Maxillary dentes molares	Posteriorly to ⑬ infratemporal space	Severe trismus*, bulging of musculus temporalis, intraoral swelling in region of tuber maxillae

* Trismus is spasm of the muscles of mastication that results in the inability to open the mouth.

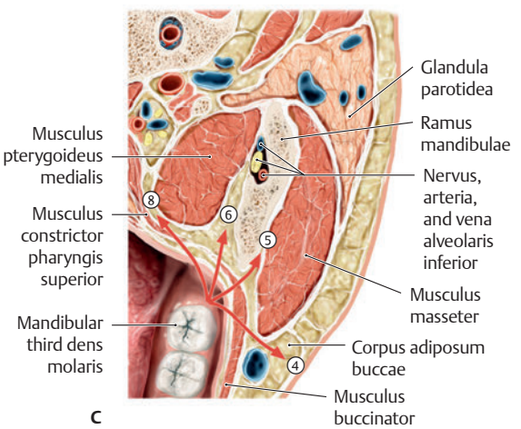


Fig. 8.60 **Potential routes for the spread of infection from apical dental abscesses**

A Sagittal section through dentes canini (anterior teeth). **B** Coronal section through dentes molares (posterior teeth). **C** Transverse section of area posterior to the third dens molaris, superior view.

Apical dental infections may spread to a number of regions in the head and neck, including the superficial facial space, the palatum, the vestibulum oris, the sinus maxillaris, and the sublingual, submandibular, and submental spaces. Infections entering into the sublingual and submandibular spaces may ultimately reach the mediastinum through their posterior communications with the parapharyngeal spaces; these spaces in turn communicate with the retropharyngeal space and the vaginae caroticae. Infections in mandibular third dentes molares may spread to the buccal, submasseteric, pterygopalatine, and parapharyngeal spaces.

Bones of the Orbita

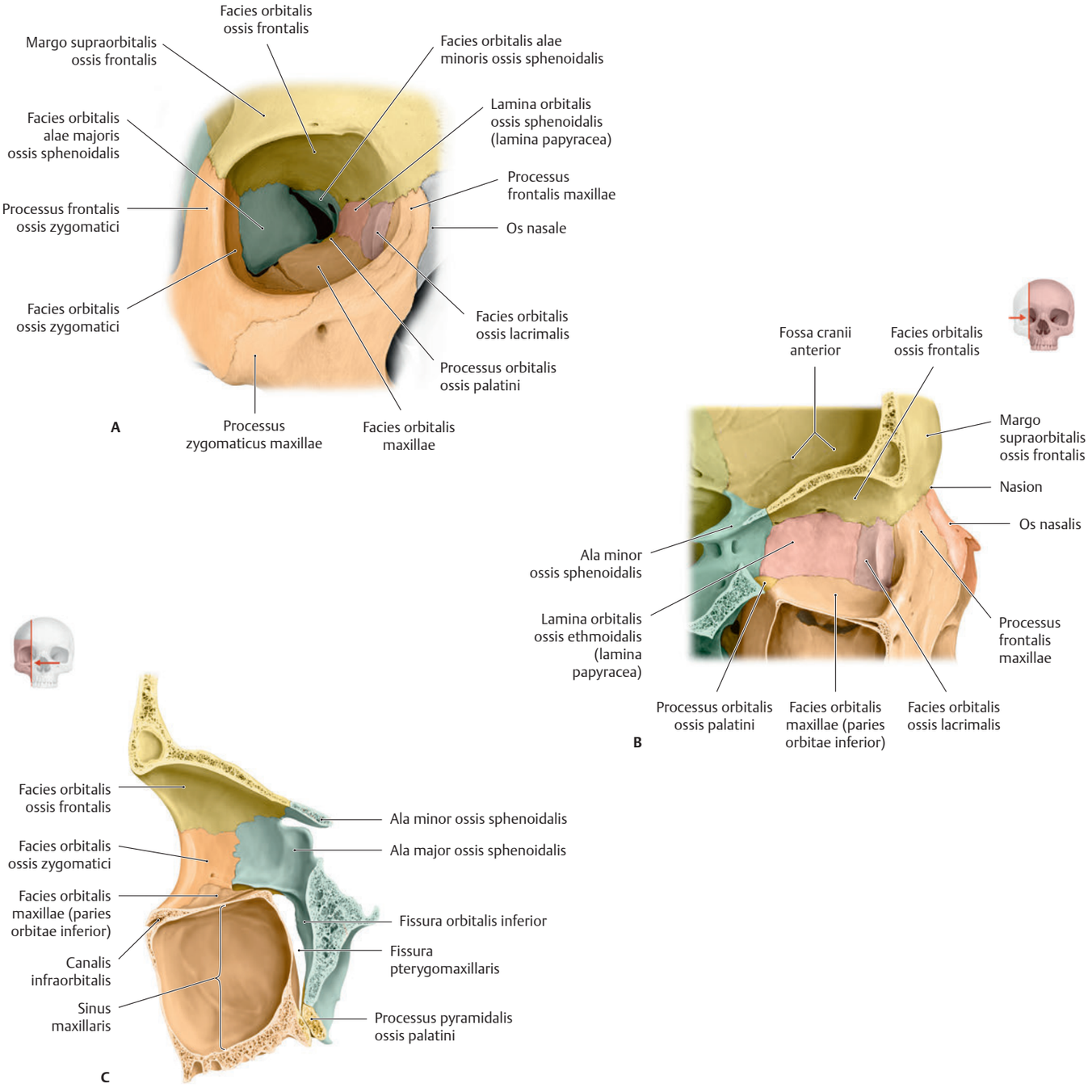
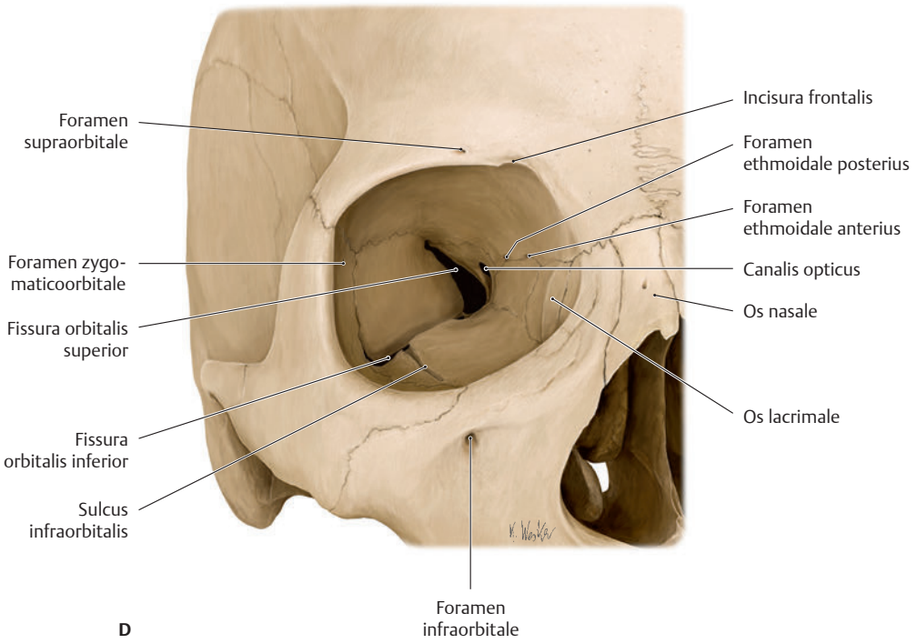
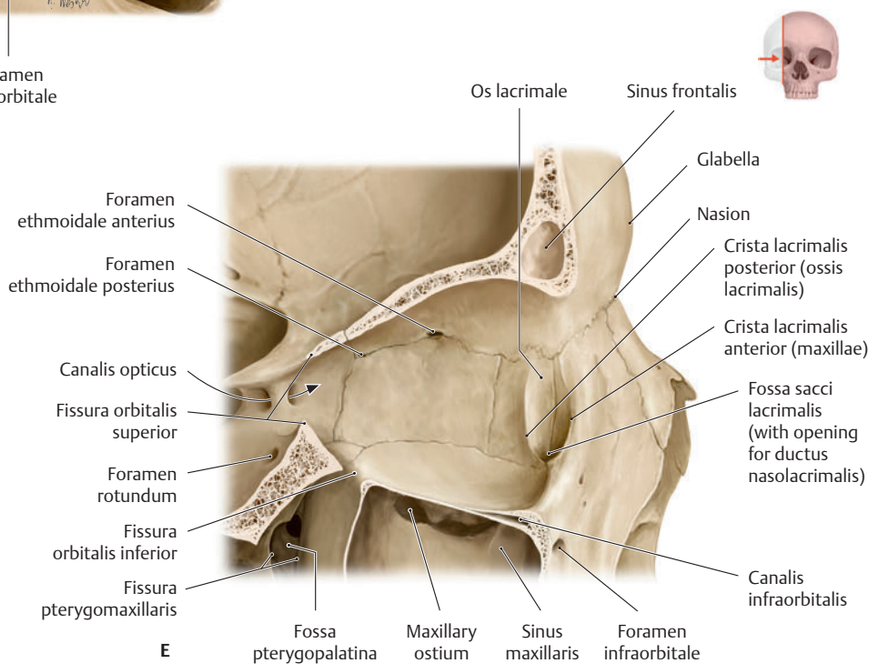


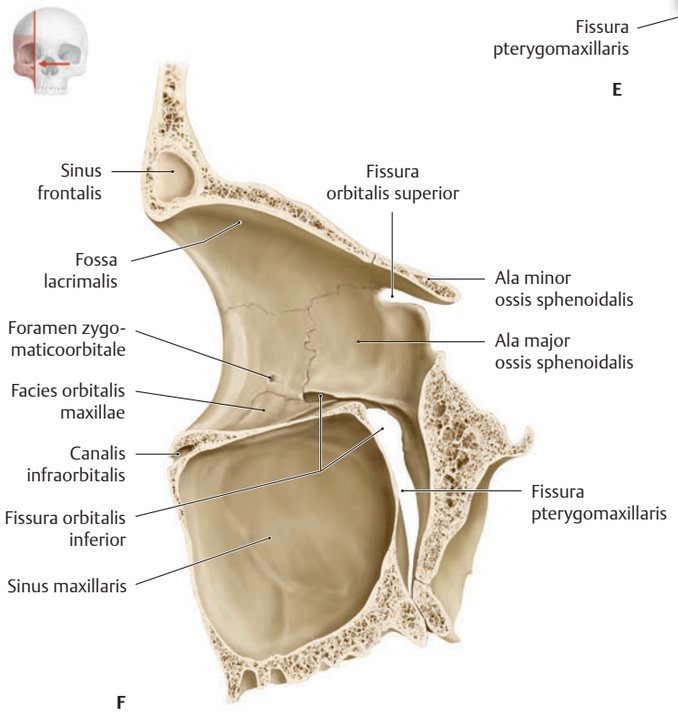
Fig. 9.1 **Bones of the orbita**
Right orbita. **A,D** Anterior view. **B,E** Lateral view with paries orbitae lateralis removed. **C,F** Medial view with paries orbitae medialis removed. The orbita is formed by seven bones: the ossa frontale, zygomaticum, ethmoidale, sphenoidale, lacrimale, and palatinum, and the maxilla. The neurovascular structures of the orbita communicate with the surrounding spaces via several major passages (see **Table 9.1**): the fissurae orbitales superior and fissura orbitalis inferior, the canalis opticus, the foramina ethmoidalia anterius and posterius, the canalis infraorbitalis, and the ductus nasolacrimalis. The neurovascular structures of the orbita also communicate with the superficial face by passing through the orbital rim. *Note:* The exposed sinus maxillaris can be seen in **E**. The hiatus maxillaris contains the ostium by which the sinus maxillaris opens into the cavitas nasi superior to the concha nasi inferior. The fissura orbitalis inferior is contiunuous inferoposteriorly with the fissura pterygomaxillaris, which is the boundary between the fossae infratemporalis and pterygopalatina. The fossa infratemporalis is on the lateral side of the fissura pterygomaxillaris; the fossa pterygopalatina is on the medial side.


Foramen supraorbitale
Foramen zygo-maticoorbitale
Fissura orbitalis superior
Fissura orbitalis inferior
Sulcus infraorbitalis
Foramen infraorbitale
Incisura frontalis
Foramen ethmoidale posterius
Foramen ethmoidale anterius
Canalis opticus
Os nasale
Os lacrimale

D


Os lacrimale
Sinus frontalis
Glabella
Nasion
Crista lacrimalis posterior (ossis lacrimalis)
Crista lacrimalis anterior (maxillae)
Fossa sacci lacrimalis (with opening for ductus nasolacrimalis)
Canalis infraorbitalis
Foramen ethmoidale anterius
Foramen ethmoidale posterius
Canalis opticus
Fissura orbitalis superior
Foramen rotundum
Fissura orbitalis inferior
Fissura pterygomaxillaris
Fossa pterygopalatina
Maxillary ostium
Sinus maxillaris
Foramen infraorbitale

E


Sinus frontalis
Fossa lacrimalis
Foramen zygo-maticoorbitale
Facies orbitalis maxillae
Canalis infraorbitalis
Fissura orbitalis inferior
Sinus maxillaris
Fissura orbitalis superior
Ala minor ossis sphenoidalis
Ala major ossis sphenoidalis
Fissura pterygomaxillaris

F

Communications of the Orbita

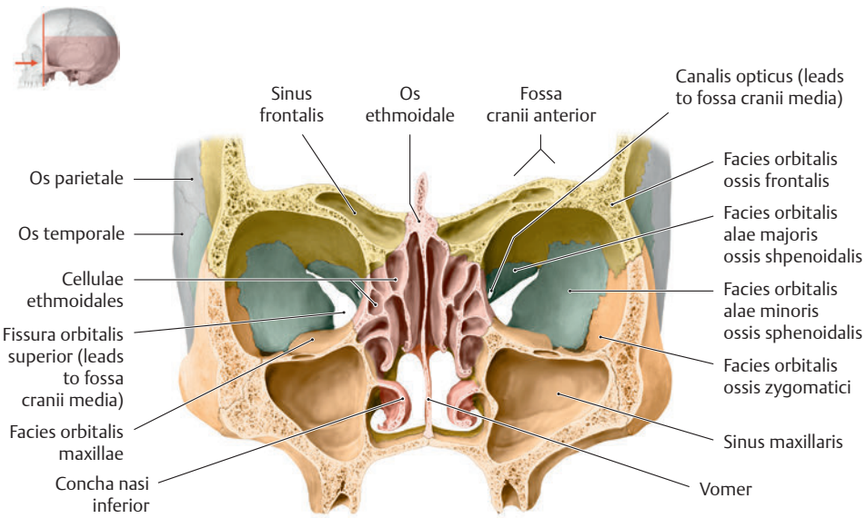


Fig. 9.2 **Bones of the orbita and adjacent cavities**
Coronal section, anterior view. The bones of the orbita also form portions of the walls of neighboring cavities. Disease processes may originate in the orbita and spread to these cavities, or originate in these cavities and spread to the orbita.

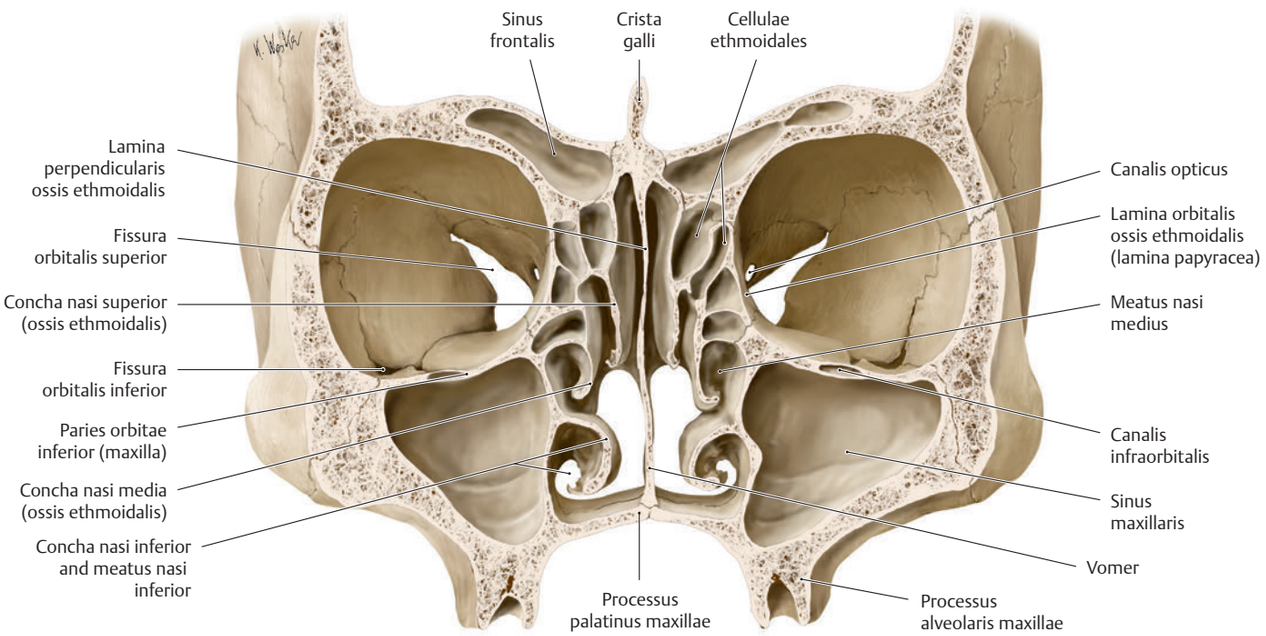


Fig. 9.3 **Orbitae and neighboring structures**
Coronal section through both orbitae, anterior view. The walls separating the orbita from the cellulae ethmoidales (0.3 mm, lamina papyracea) and from the sinus maxillaris (0.5 mm, paries orbitae inferior) are very thin. Thus, both of these walls are susceptible to fractures and provide routes for the spread of tumors and inflammatory processes into or out of the orbita. The fissura orbitalis superior communicates with the fossa cranii media, and so several structures that are not pictured here—the sinus sphenoidalis, glandula pituitaria, and chiasma opticum—are also closely related to the orbita.

Table 9.1 **Communications of the orbita**

Structure	Communicates	Via	Neurovascular structures in canal/fissure
Sinus frontalis and cellulae ethmoidales anteriores	Superiorly	Unnamed canaliculi	• Sensory filaments
	Medially	Foramen ethmoidale anterius	• Arteria ethmoidalis anterior (from arteria ophthalmica) • Vena ethmoidalis anterior (to vena ophthalmica superior) • Nervus ethmoidalis anterior (CN V_1)
Sinus sphenoidalis and cellulae ethmoidales posteriores	Medially	Foramen ethmoidale posterius	• Arteria ethmoidalis posterior (from arteria opthalmica) • Vena ethmoidalis posterior (to vena ophthalmica superior) • Nervus ethmoidalis posterior (CN V_1)
Fossa cranii media	Posteriorly	Fissura orbitalis superior	• Nervi craniales to the extraocular muscles (nervi oculomotorius [CN III], trochlearis [CN IV], and abducens [CN VI]) • Nervus ophthalmicus (CN V_1) and branches: ◦ Nervus lacrimalis ◦ Nervus frontalis (branches into nervi supraorbitalis and supratrochlearis) ◦ Nervus nasociliaris • Vena ophthalmica superior (and occasionally inferior) (to sinus cavernosus) • Ramus meningeus recurrens of arteria lacrimalis (anastomoses with arteria meningea media)
	Posteriorly	Canalis opticus	• Nervus opticus (CN II) • Arteria ophthalmica (from arteria carotis interna)
Fossa pterygopalatina	Posteroinferiorly (medially)	Fissura orbitalis inferior*	• Arteria infraorbitalis (from arteria maxillaris) • Infraorbital v. (to Plexus pterygoideus)* • Nervus infraorbitalis (CN V_2) • Nervus zygomaticus (CN V_2) • Vena ophthalmica inferior (variable, to sinus cavernosus)
Fossa infratemporalis	Posteroinferiorly (laterally)		
Cavitas nasi	Inferomedially	Canalis nasolacrimalis	• Ductus nasolacrimalis
Sinus maxillaris	Inferiorly	Unnamed canaliculi	• Sensory filaments
Face and Fossa temporalis	Anteriorly	Foramen zygomaticofaciale	• Ramus zygomaticofacialis (CN V_2) • Ramus anastomoticus arteriae lacrimalis (to arteriae transversa faciei and zygomaticoorbitalis)
		Foramen zygomaticotemporale	• Ramus zygomaticotemporalis (CN V_2) • Ramus anastomoticus arteriae lacrimalis (to arteriae temporales profundae)
Face	Anteriorly	Foramen supraorbitale (incisura supraorbitalis)	• Ramus lateralis nervi supraorbitalis (CN V_1) • Arteria supraorbitalis (from arteria ophthalmica) • Vena supraorbitalis (to vena angularis)
		Incisura frontalis	• Arteria supratrochlearis (from arteria ophthalmica) • Nervus supratrochlearis (CN V_1) • Ramus medialis nervi supraorbitalis (CN V_1)
		Orbital rim, medial aspect	• Nervus infratrochlearis (CN V_1) • Arteria dorsalis nasi (from arteria ophthalmica) • Dorsal nasal v. (to vena angularis)
		Orbital rim, lateral aspect	• Nerus lacrimalis (CN V_1) • Arteria lacrimalis (from arteria ophthalmica) • Vena lacrimalis (to vena ophthalmica superior)

* The arteria, vena and nervus infraorbitalis travel in the canalis infraorbitalis on the paries orbitae inferior and emerge at the fissura orbitalis inferior. The fissura orbitalis inferior is continuous inferiorly with the fissura pterygomaxillaris, which is the boundary between the fossae infratemporalis and pterygopalatina. The fassa infratemporalis lies on the lateral side of the fissura pterygomaxillaris; the fossa pterygopalatina lies on the medial side.

Extraocular Muscles

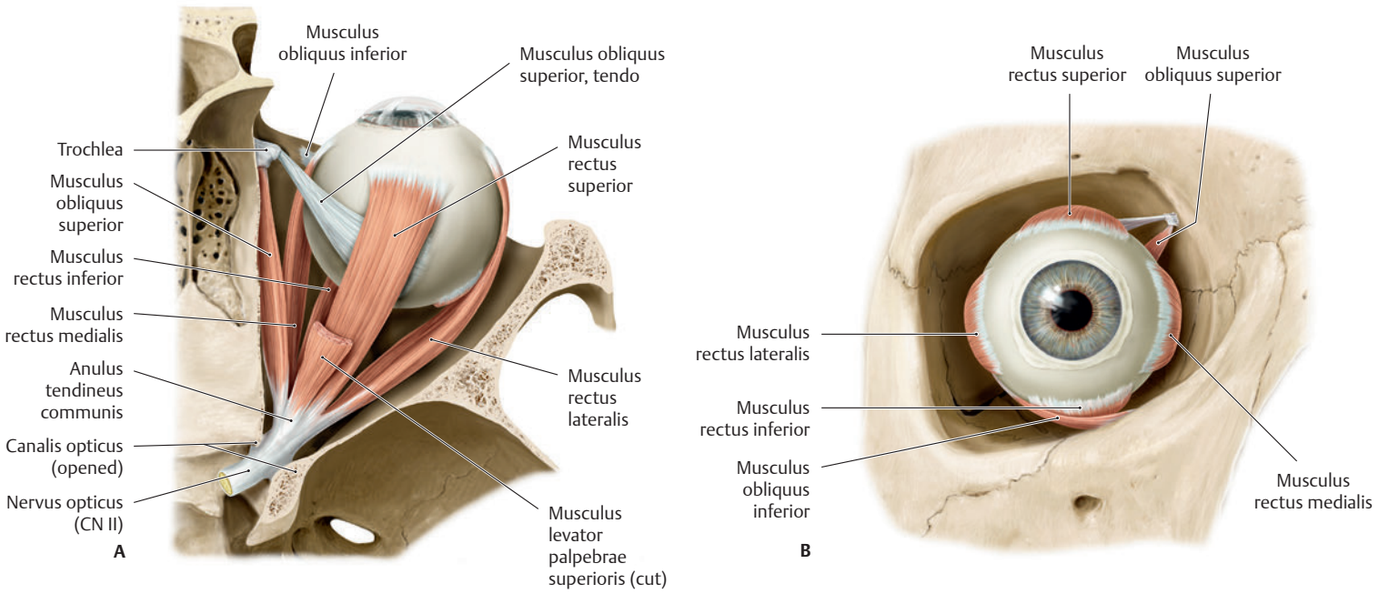


Fig. 9.4 **Extraocular (extrinsic eye) muscles**
Right eye. **A** Superior view. **B** Anterior view. The bulbus oculi is moved in the orbita by four musculi recti (superior, medialis, inferior, lateralis) and two musculi obliqui (superior and inferior). The four rectus muscles arise from a tendinous ring around the canalis opticus (anulus tendineus communis) and insert on the sclera of the bulbus oculi. The musculi obliqui superior and inferior arise from the corpus ossis sphenoidalis and the medial orbital margin of the maxilla, respectively. The musculus obliquus superior passes through a tendinous loop (trochlea) attached to the superomedial orbital margin (os frontale); this redirects it at an acute angle to its insertion on the superior surface of the bulbus oculi. The coordinated interaction of all six functionally competent extraocular muscles is necessary for directing both eyes toward the visual target. The brain then processes the two perceived retinal images in a way that provides binocular vision perception. Impaired function of one or more extraocular muscles causes deviation of the eye from its normal position, resulting in diplopia (double vision). This impaired function may be due to trauma to CN III, IV, and VI or due to diseases that affect nerves, e.g., multiple sclerosis (MS) or diabetes.

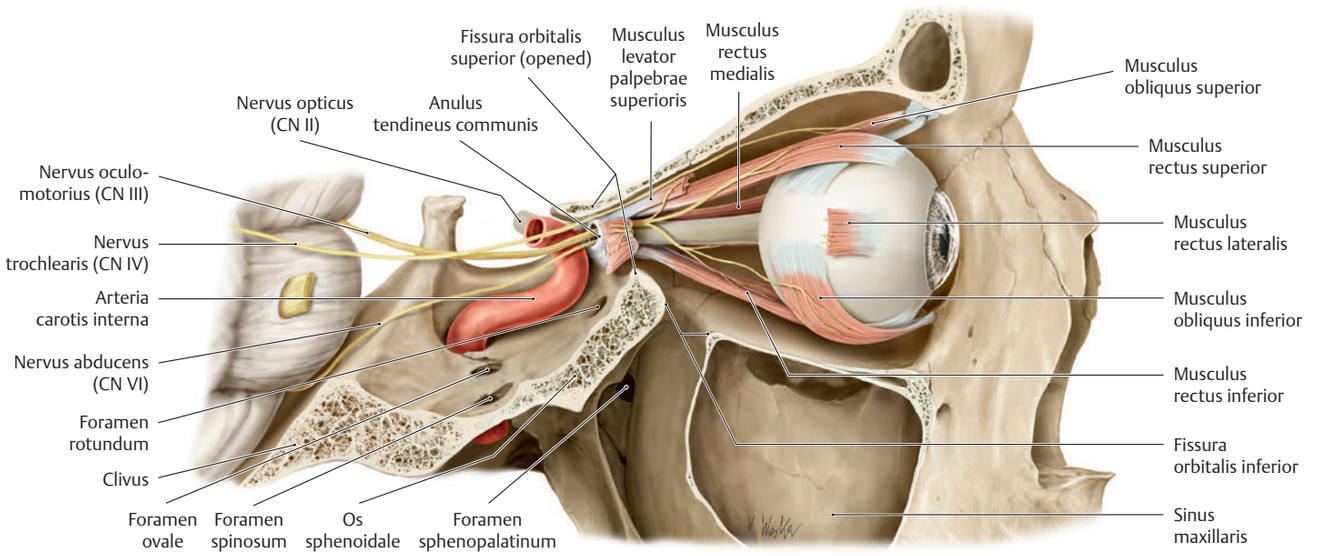


Fig. 9.5 **Innervation of the extraocular muscles**
Right eye, lateral view with the paries orbitae lateralis removed. The extraocular muscles are supplied by nervi craniales III, IV, and VI (see **Table 9.2**). *Note:* The musculus levator palpebrae superioris is also supplied by CN III. After emerging from the truncus encephali, these cranial nerves first traverse the sinus cavernosus, where they are in close proximity to the arteria carotis interna. From there they pass through the fissura orbitalis superior to enter the orbita and supply their respective muscles. The nervus opticus (CN II) enters the orbita via the more medially located canalis opticus (see **Fig. 9.1D**).

***Fig. 9.6* Actions of the extraocular muscles**
Right eye, superior view with paries orbitae superior removed. Primary actions (red), secondary actions (blue).

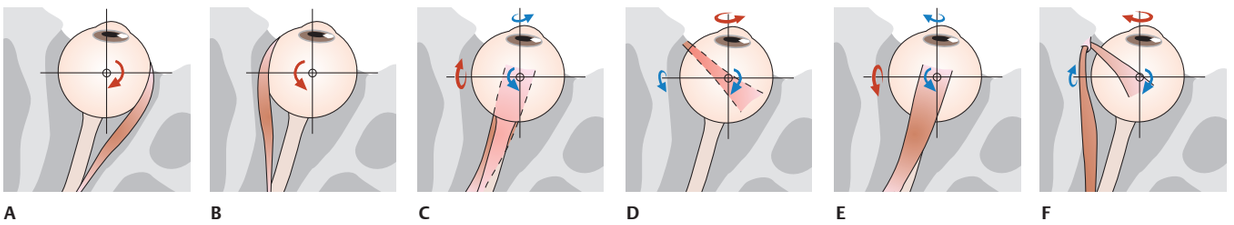


***Table 9.2* Actions and innervation of the extraocular muscles**

Muscle	Primary action	Secondary action	Innervation
A Musculus rectus lateralis	Abduction	–	Nervus abducens (CN VI)
B Musculus rectus medialis	Adduction	–	Nervus oculomotorius (CN III), ramus inferior
C Musculus rectus inferior	Depression	Adduction and lateral rotation	
D Musculus obliquus inferior	Elevation and abduction	Lateral rotation	
E Musculus rectus superior	Elevation	Adduction and medial rotation	Nervus oculomotorius (CN III), ramus superior
F Musculus obliquus superior	Depression and abduction	Medial rotation	Nervus trochlearis (CN IV)

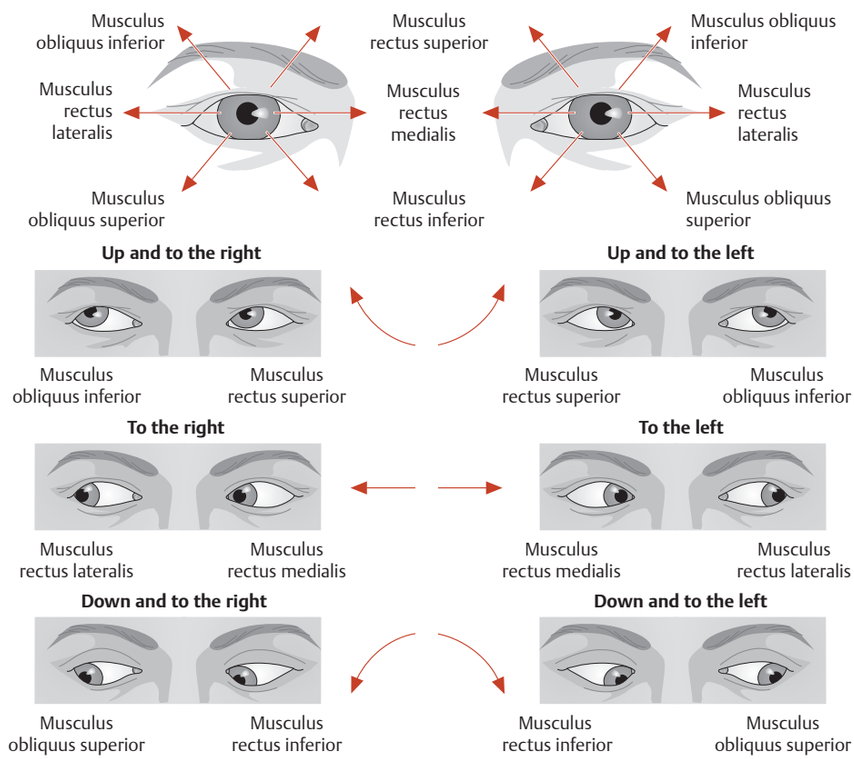


***Fig. 9.7* The six cardinal directions of gaze**
In the clinical evaluation of ocular motility to diagnose *oculomotor palsies*, six cardinal directions of gaze are tested (see arrows). Note that different muscles may be activated in each eye for any particular direction of gaze. For example, gaze to the right is effected by the combined actions of the musculus rectus lateralis of the right eye and the musculus rectus medialis of the left eye. These two muscles, moreover, are supplied by different nervi craniales (VI and III, respectively).
If one muscle is weak or paralyzed, deviation of the eye will be noted during certain ocular movements (see **Fig. 9.9**).

Innervation of the Extraocular Muscles (CN III, IV, & VI)

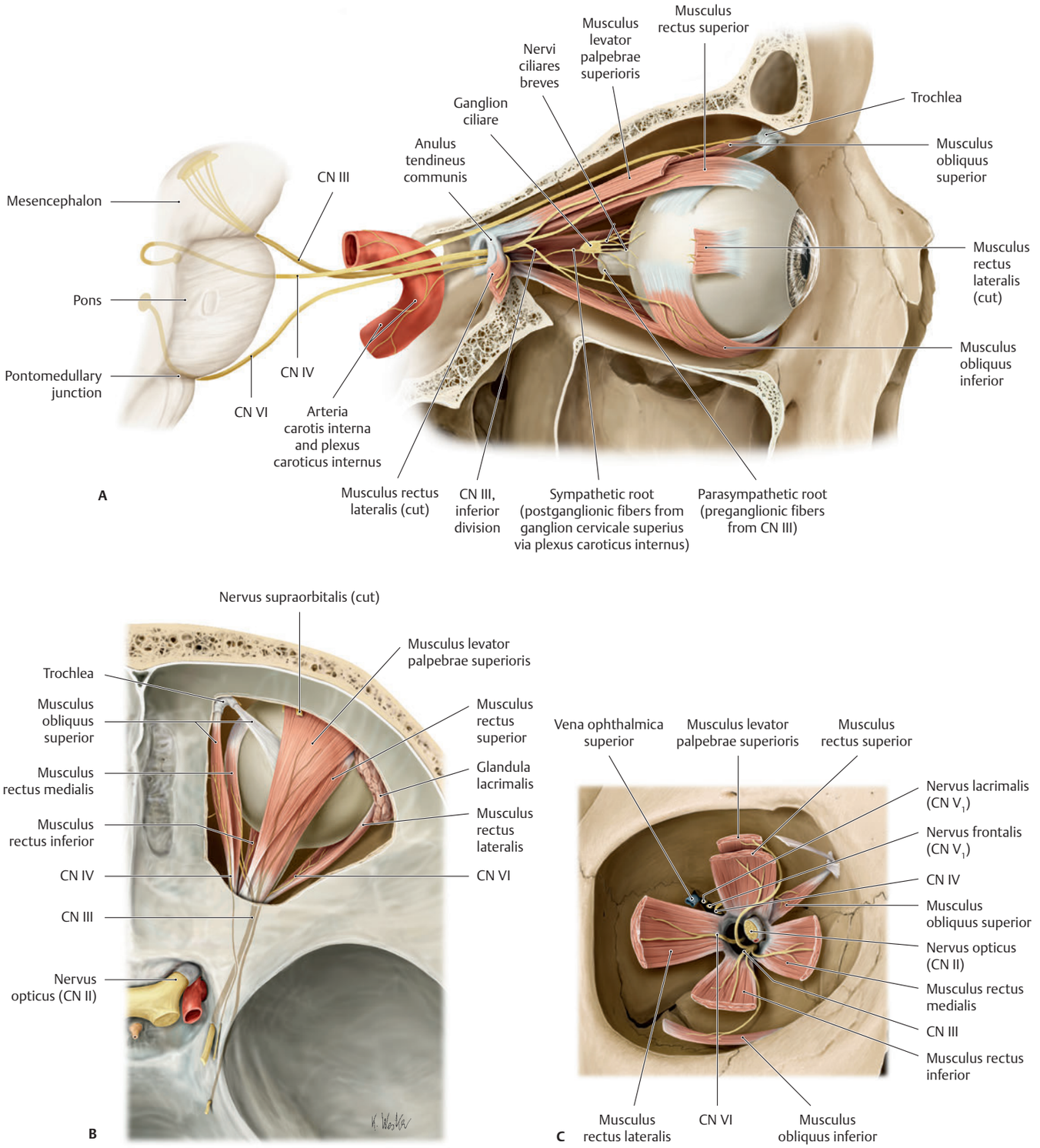


Fig. 9.8 **Nerves supplying the ocular muscles**
Right orbita. **A** Lateral view with paries orbitae lateralis removed. **B** Superior view of opened orbita. **C** Anterior view. Nervi craniales III, IV, and VI enter the orbita through the fissura orbitalis superior, lateral to the canalis opticus (CN IV then passes lateral to the anulus tendineus communis, and CN III and VI pass through it). All three nerves supply somatomotor innervation to the extraocular muscles. See Chapter 4 for a full discussion of CN III, IV, and VI. Of the three, only the nervus oculomotorius (CN III) contains both somatic and visceral fibers; it is also the only one that innervates multiple extraocular and intraocular muscles.

***Fig. 9.9* Oculomotor palsies**
Palsy of the right side shown during attempted straight-ahead gaze. **A** Complete oculomotor palsy. **B** Trochlear palsy. **C** Abducent palsy. Oculomotor palsies may result from lesions involving the cranial nerve nucleus, the course of the nerve, or the eye muscle itself. Depending on the involved muscle, symptoms may include deviated position of the affected eye and diplopia. The patient attempts to compensate for this by adjusting the position of the head.

A Complete oculomotor (CN III) palsy: Affects four extraocular muscles, two intraocular muscles (see **Table 9.3**), and the musculus levator palpebrae superioris. Symptoms and affected muscle(s): Bulbus oculi deviates toward lower outer quadrant = disabled musculi recti superior, inferior, and medialis and musculus obliquus inferior. Mydriasis (pupil dilation) = disabled musculus sphincter pupillae. Loss of near accommodation = disabled musculus ciliaris. Ptosis (drooping of palpebra) = disabled musculus levator palpebrae superioris. The rima palpebrarum cannot be opened during complete ptosis in which both the musculus levator palpebrae superioris (CN III) and tarsus superior (sympathetic) muscles are paralyzed. Diplopia will therefore not be observed.

B Trochlear nerve (CN IV) palsy: Eye deviates slightly superomedially, causing diplopia = disabled musculus obliquus superior.

C Abducent nerve (CN VI) palsy: Eye deviates medially, causing diplopia = disabled musculus rectus lateralis.

***Table 9.3* Cranial nerves of the extraocular muscles**

Course*	Fibers	Nuclei	Function	Effects of nerve injury
Nervus oculomotorius (CN III)				
Runs anteriorly from mesencephalon	Somatic efferent	Oculomotor nucleus	Innervates: • Musculus levator palpebrae superioris • Musculus rectus superior, medialis, and inferior • Musculus obliquus inferior	Complete oculomotor palsy (paralysis of extra- and intraocular muscles): • Ptosis (drooping of palpebra) • Downward and lateral gaze deviation • Diplopia (double vision) • Mydriasis (pupil dilation) • Accommodation difficulties (ciliary paralysis)
	Visceral efferent	Visceral oculomotor (Edinger-Westphal) nucleus	Synapse with neurons in ciliary ganglia. Innervates: • Musculus sphincter pupillaris • Musculus ciliaris	
Nervus trochlearis (CN IV)				
Emerges from posterior surface of truncus encephali near midline, courses anteriorly around the pedunculus cerebri	Somatic efferent	Nucleus of the nervus trochlearis	Innervates: • Musculus obliquus superior	• Diplopia • Affected eye is higher and deviated medially (dominance of musculus obliquus inferior)
Nervus abducens (CN VI)				
Follows a long extradural path**	Somatic efferent	Nucleus of the nucleus abducens	Innervates: • Musculus rectus lateralis	• Diplopia • Medial strabismus (due to unopposed action of musculus rectus medialis)

* All three nerves enter the orbita through the superior fissura orbitalis superior; CN III and CN VI pass through the anulus tendineus communis of the extraocular muscles.
** The abducent nerve follows an extradural course; abducent nerve palsy may therefore develop in association with meningitis and subarachnoid hemorrhage.

Neurovasculature of the Orbita

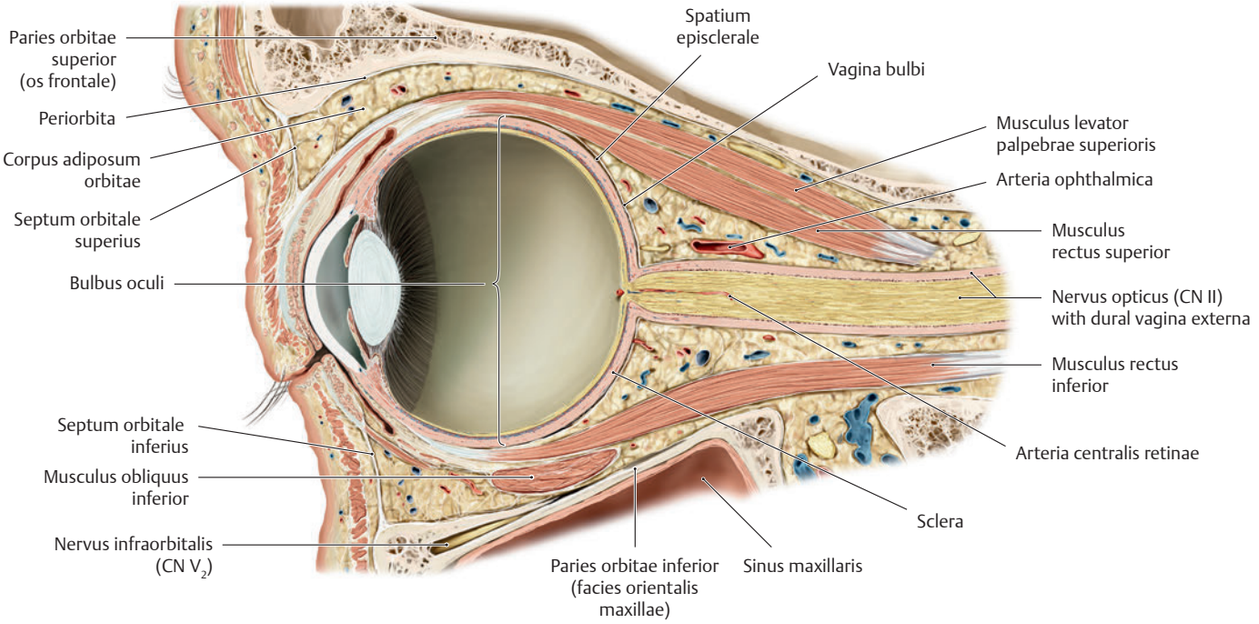


Fig. 9.10 **Upper, middle, and lower levels of the orbita**
Right orbita. Sagittal section viewed from the medial side. The orbita is lined with periosteum (periorbita) and filled with periorbital fat (corpus adiposum orbitae), which is bounded anteriorly by the septa orbitalia and toward the bulbus oculi by a mobile sheath of connective tissue (vagina bulbi). The narrow space between the vagina bulbi and sclera is called the spatium episclerale. Embedded in the periorbital fat are the bulbus oculi, nervus opticus, glandula lacrimalis, extraocular muscles, and associated neurovascular structures. Topographically, the orbita is divided into three levels:

- Upper level: paries orbitae superior to musculus levator palpebrae superioris
- Middle level: musculus rectus superior to nervus opticus
- Lower level: nervus opticus to paries orbitae inferior

Table 9.4 **Neurovascular contents of the orbita**

Orbital level	Arteries and veins	Nerves
Upper level	• Arteria lacrimalis (from arteria ophthalmica) • Vena lacrimalis (to vena ophthalmica superior) • Arteria supraorbitalis (terminal branch of arteria ophthalmicus) • Vena supraorbitalis (forms vena angularis with vena supratrochlearis)	• Nervus lacrimalis (CN V_1) • Nervus frontalis (CN V_1) and terminal branches: ◦ Nervus supraorbitalis ◦ Nervus supratrochlearis • Nervus trochlearis (CN IV)
Middle level	• Arteria ophthalmica (from Arteria carotis interna) and branches: ◦ Arteria centralis retinae ◦ Arteriae ciliares posteriores • Vena ophthalmica superior (to sinus cavernosus)	• Nervus nasociliaris (CN V_1) • Nervus abducens (CN VI) • Nervus oculomotorius (CN III), ramus superior and fibers from ramus inferior (to ganglion ciliare) • Nervus opticus (CN II) • Ganglion ciliare and roots: ◦ Parasympathetic root (presynaptic autonomic fibers from CN III) ◦ Sympathetic root (postsynaptic fibers from ganglion cervicale superius) ◦ Sensory root (sensory fibers from bulbus oculi to nervus nasociliaris) • Nervi ciliares breves (fibers from/to ganglion ciliare)
Lower level	• Arteria infraorbitalis (terminal branch of arteria maxillaris) • Vena ophthalmica inferior (to sinus cavernosus and/or plexus pterygoideus)	• Nervus infraorbitalis (CN V_2) • Nervus oculomotorius (CN III), ramus inferior

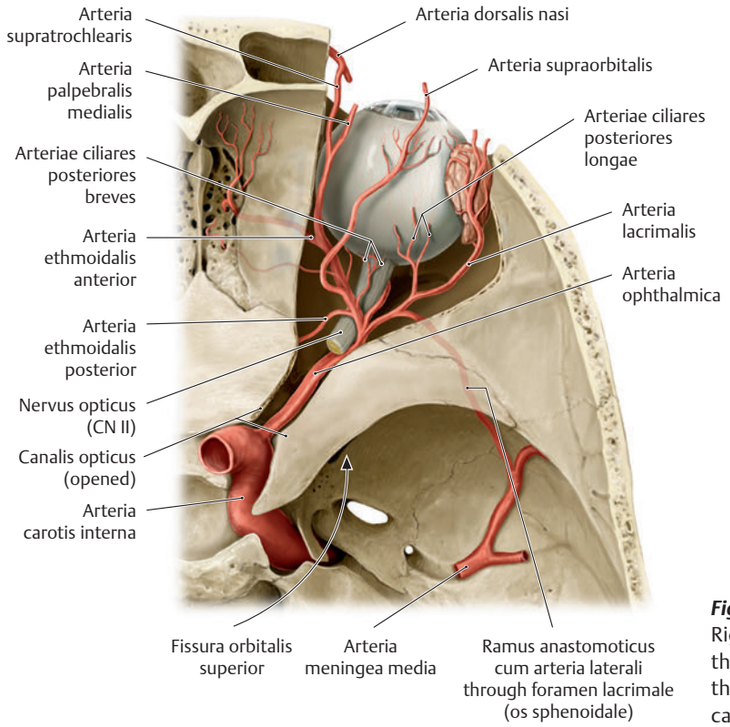


Fig. 9.11 **Branches of the arteria ophthalmica**
Superior view of opened right orbita. While running below CN II in the canalis opticus, the arteria ophthalmica gives off the arteria centralis retinae, which pierces and travels with CN II. The arteria ophthalmica then exits the canal and branches to supply the intraorbital structures (including the bulbus oculi).

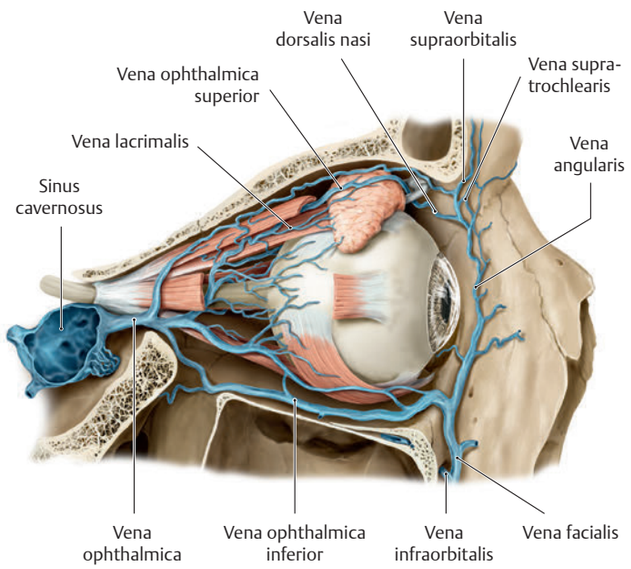


Fig. 9.12 **Veins of the orbita**
Right orbita, lateral view with the paries orbitae lateralis removed and the sinus maxillaris opened. The veins of the orbita communicate with the veins of the superficial and deep facial region and with the sinus cavernosus (potential spread of infectious pathogens, see **Fig. 3.23**).

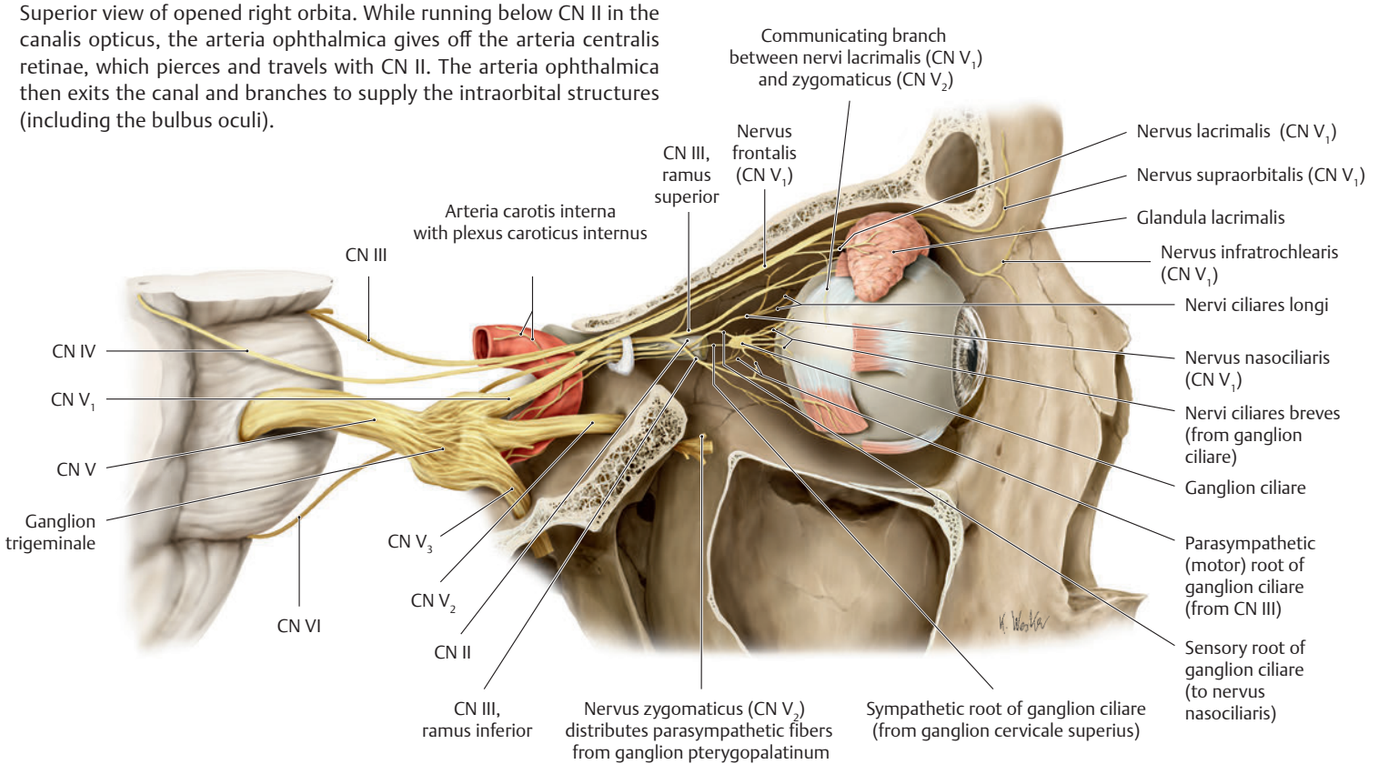


Fig. 9.13 **Innervation of the orbita**
Lateral view of opened right orbita. The extraocular muscles receive motor innervation from three nervi craniales: nervi oculomotorius (CN III), trochlear (CN IV), and abducens (CN VI). The ganglion ciliare distributes parasympathetic fibers to the intraocular muscles via the nervi ciliares breves. Parasympathetic fibers reach the ganglion via the ramus inferior of CN III. Sympathetic fibers from the ganglion cervicale superius travel along the arteria carotis interna to the fissura orbitalis superior. In the orbita, sympathetic fibers run with the nervus nasociliaris (CN V_1) and/or arteria ophthalmica and pass through the ganglion ciliare (the nervus nasociliaris also gives off direct sensory branches, the nervi ciliares longi, which may carry postganglionic sympathetic fibers). Sensory fibers from the bulbus oculi pass through the ganglion ciliare to the nervus nasociliaris (CN V_1). *Note:* Parasympathetic fibers to the glandula lacrimalis are distributed by the nervus lacrimalis (CN V_1), which communicates with the nervus zygomaticus (CN V_2) via a communicating branch from the ramus zygomaticotemporalis. The nervus zygomaticus distributes "hitchhiking" the postganglionic fibers from the ganglion pterygopalatinum (the preganglionic fibers arise from CN VII).

Topography of the Orbita (I)

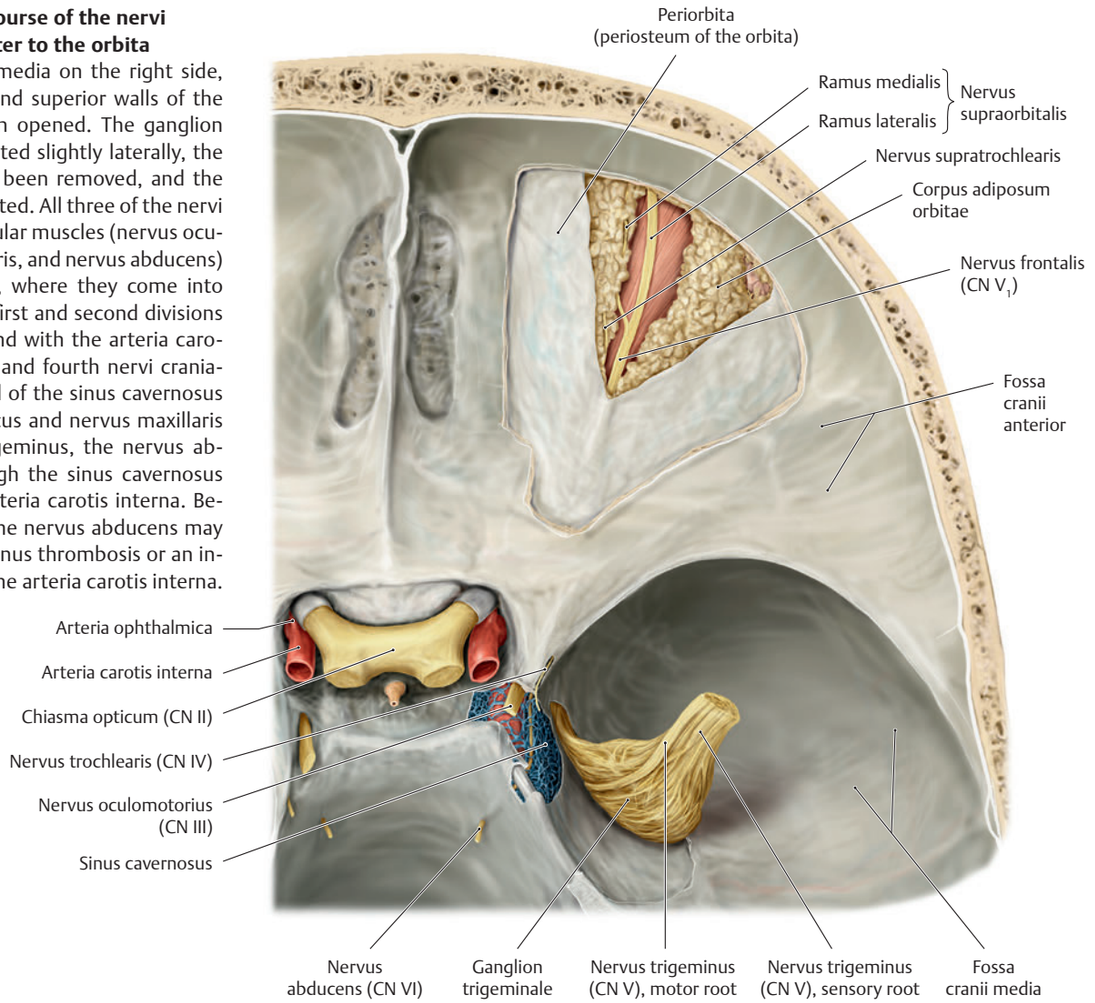


Fig. 9.14 **Intracavernous course of the nervi craniales that enter to the orbita**

Fossae cranii anterior and media on the right side, superior view. The lateral and superior walls of the sinus cavernosus have been opened. The ganglion trigeminale has been retracted slightly laterally, the paries orbitae superior has been removed, and the periorbita has been fenestrated. All three of the nervi craniales that supply the ocular muscles (nervus oculomotorius, nervus trochlearis, and nervus abducens) enter the sinus cavernosus, where they come into close relationship with the first and second divisions of the nervus trigeminus and with the arteria carotis interna. While the third and fourth nervi craniales course in the lateral wall of the sinus cavernosus with the nervus ophthalmicus and nervus maxillaris divisions of the nervus trigeminus, the nervus abducens runs directly through the sinus cavernosus in close proximity to the arteria carotis interna. Because of this relationship, the nervus abducens may be damaged as a result of sinus thrombosis or an intracavernous aneurysm of the arteria carotis interna.

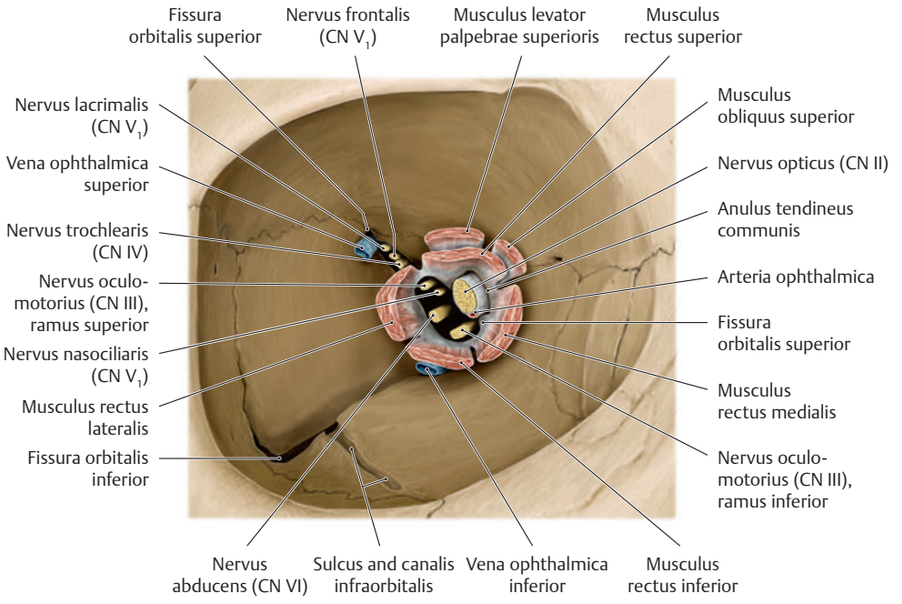


Fig. 9.15 **Neurovasculature in the canalis opticus and fissura orbitalis superior**

Right orbita, anterior view with most of the orbital contents removed.

Canalis opticus: nervus opticus (CN II) and arteria ophthalmica.

Fissura orbitalis superior (inside anulus tendineus communis): nervi abducens (CN VI), nasociliaris (CN V_1), and oculomotorius (CN III).

Fissura orbitalis superior (outside anulus tendineus communis): venae opthalmicae superior and inferior, nervi frontalis (CN V_1), lacrimalis (CN V_1), and trochlearis (CN IV).

Fissura orbitalis inferior (contents not shown): nervus zygomaticus (CN V_2) and branches of CN V_2, arteria and vena infraorbitalis, and nervus infraorbitalis in canalis infraorbitalis.

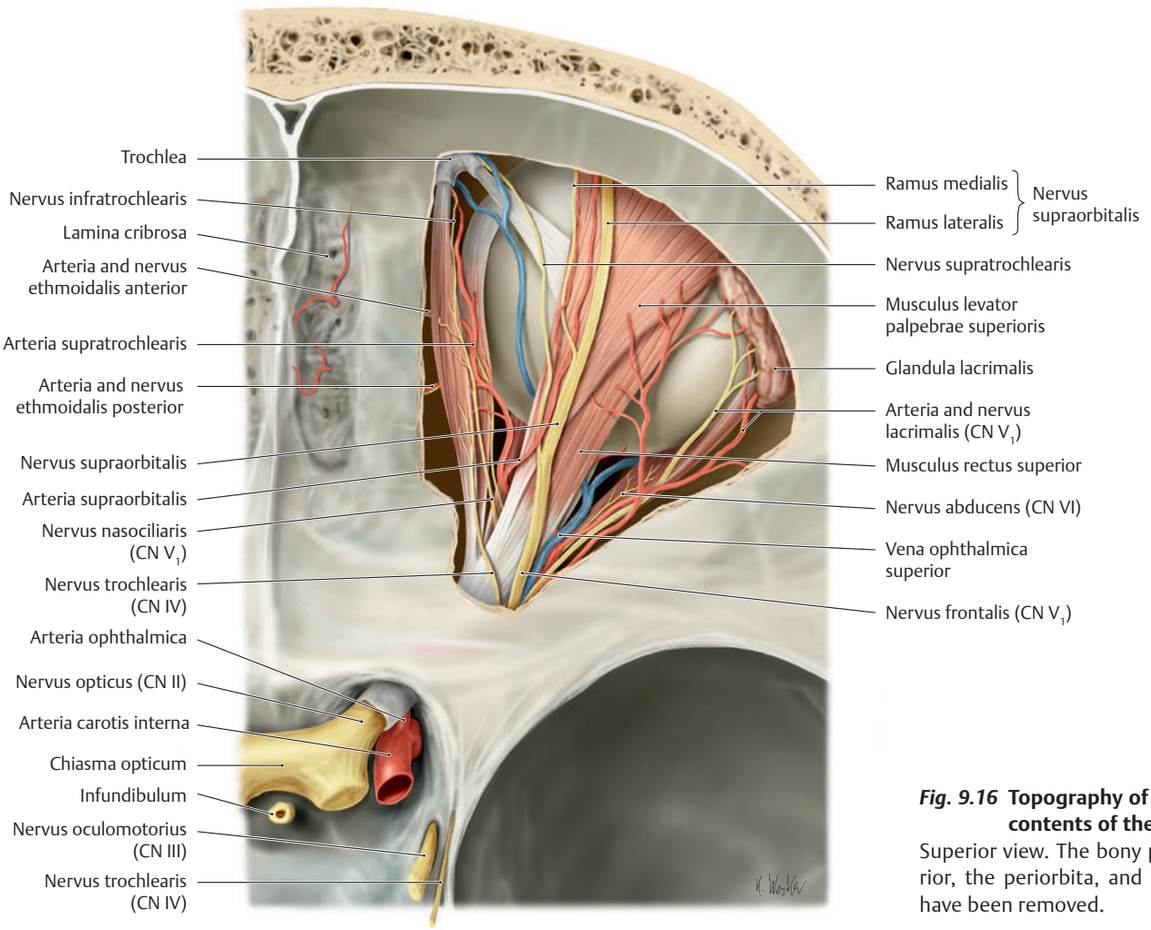


Fig. 9.16 **Topography of the right orbita: contents of the upper level**
Superior view. The bony paries orbitale superior, the periorbita, and the retro-orbital fat have been removed.

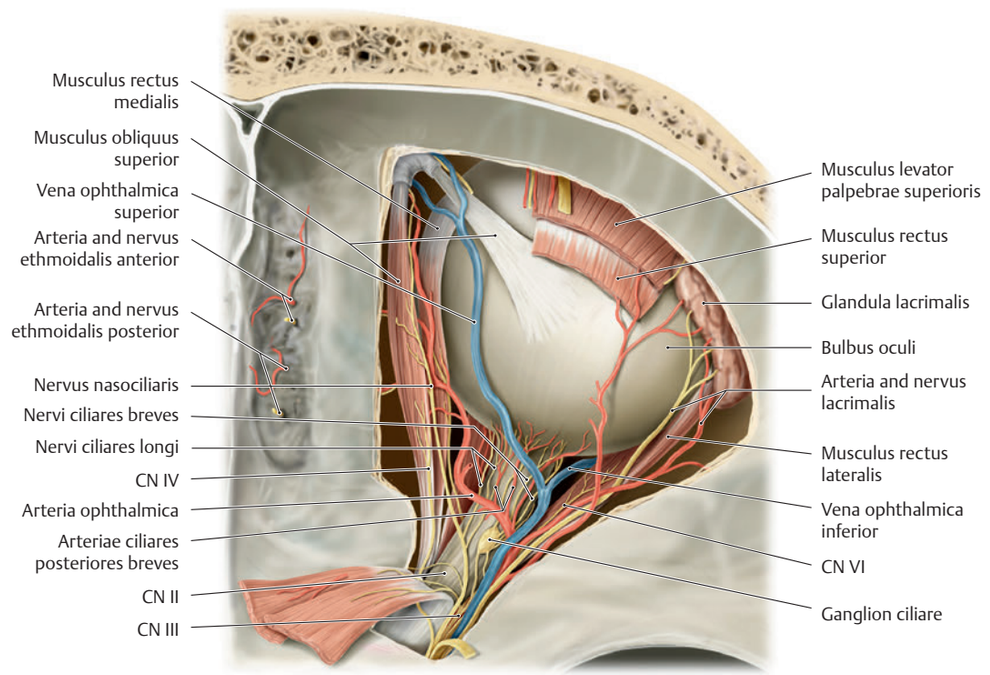
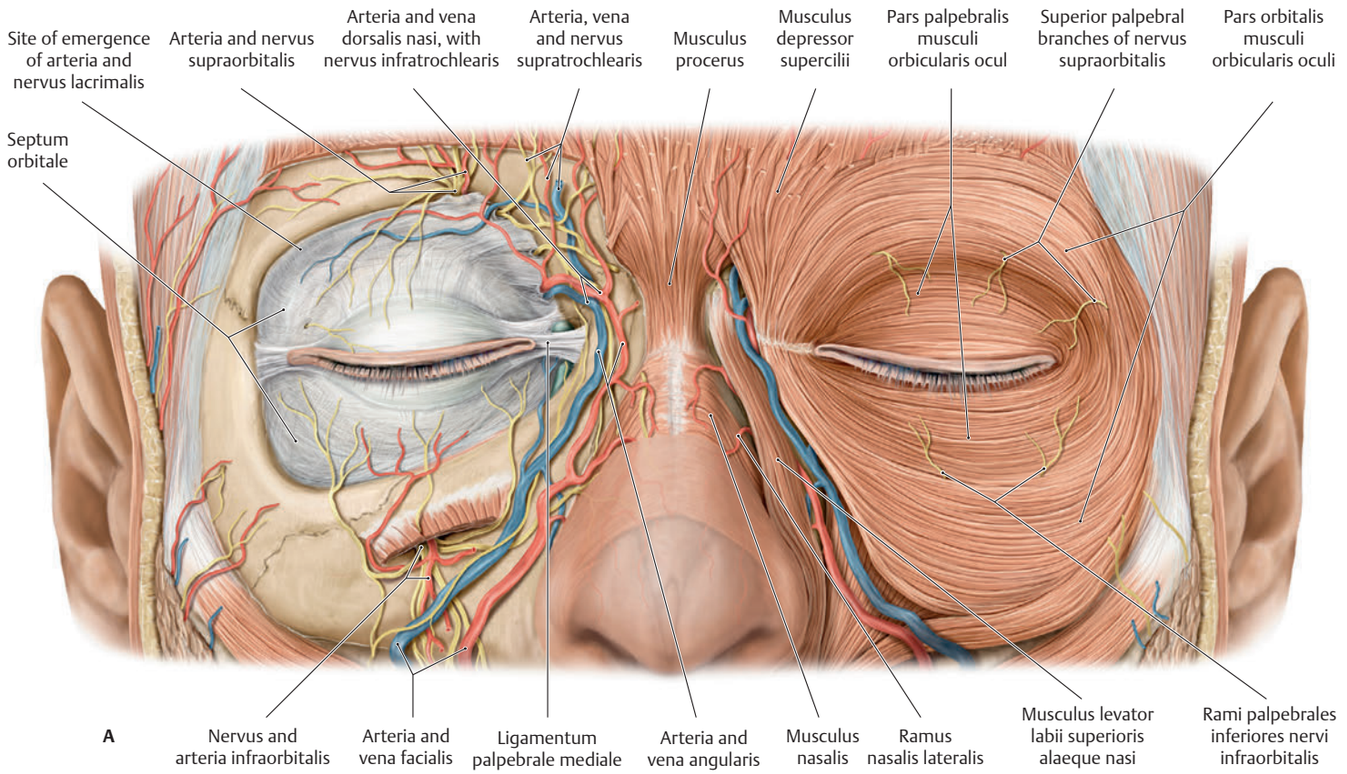


Fig. 9.17 **Topography of the right orbita: contents of the middle level**
Superior view. The musculus levator palpebrae superioris and the musculus superior rectus have been divided and reflected backward, and all fatty tissue has been removed to better expose the nervus opticus.
Note: The ganglion ciliare is approximately 2 mm in diameter and lies lateral to the nervus opticus approximately 2 cm behind the bulbus oculi. The ganglion ciliare relays parasympathetic fibers to the eye and intraocular muscles via the nervi ciliares breves. The nervi ciliares breves also contain sensory and sympathetic fibers (see **Fig. 9.13**).

Topography of the Orbita (II)



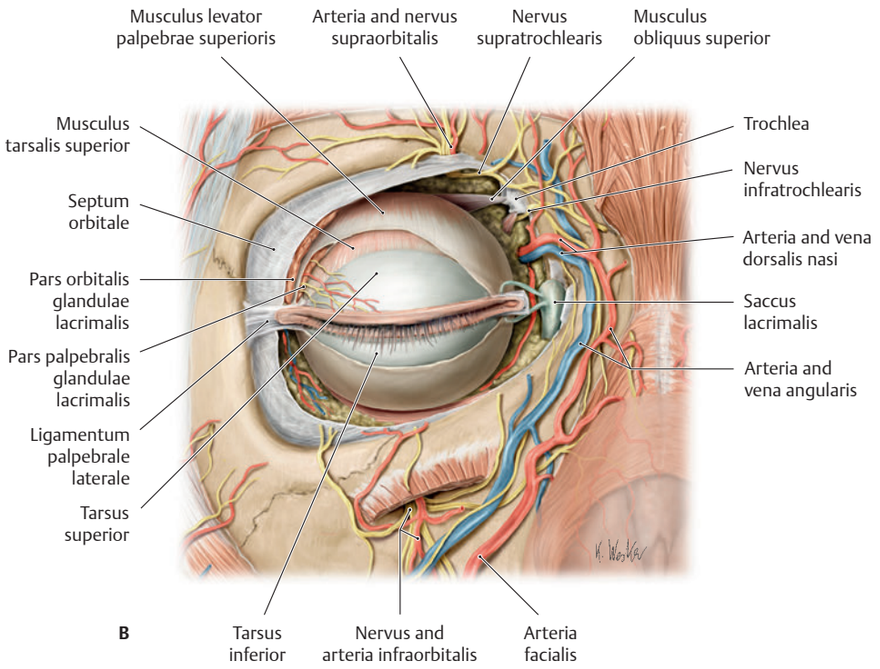


Fig. 9.18 **Superficial and deep neurovascular structures of the orbital region**

Right eye, anterior view.

A Superficial layer. The orbital septum on the right side has been exposed by removal of the musculus orbicularis oculi. **B** Deep layer. Anterior orbital structures have been exposed by partial removal of the septum orbitale.

The regions supplied by the arteria carotis *interna* (arteria supraorbitalis) and arteria carotis *externa* (arteria infraorbitalis, arteria facialis) meet in this region. The extensive anastomosis between the vena angularis (extracranial) and venae ophthalmicae superiores (intracranial) creates a portal of entry by which microorganisms may reach the sinus cavernosus (risk of sinus thrombosis, meningitis, see p. 66). It is sometimes necessary to ligate this anastomosis in the orbital region, as in patients with extensive infections of the external facial region.

Note the passage of the nervi supra- and infraorbitalis (branches of CN V_1 and CN V_2) through the accordingly named foramina. The sensory function of these two nervus trigeminus divisions can be tested at these nerve exit points.

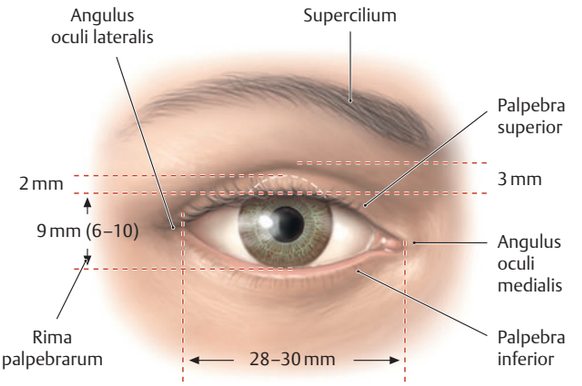


Fig. 9.19 **Surface anatomy of the eye**
Right eye, anterior view. The measurements indicate the width of the normal rima palpebrarum. It is important to know these measurements because there are a number of diseases in which they are altered. For example, the rima palpebrarum may be widened in peripheral facial paralysis or narrowed in ptosis (drooping of the palpebrae) due to oculomotor palsy.

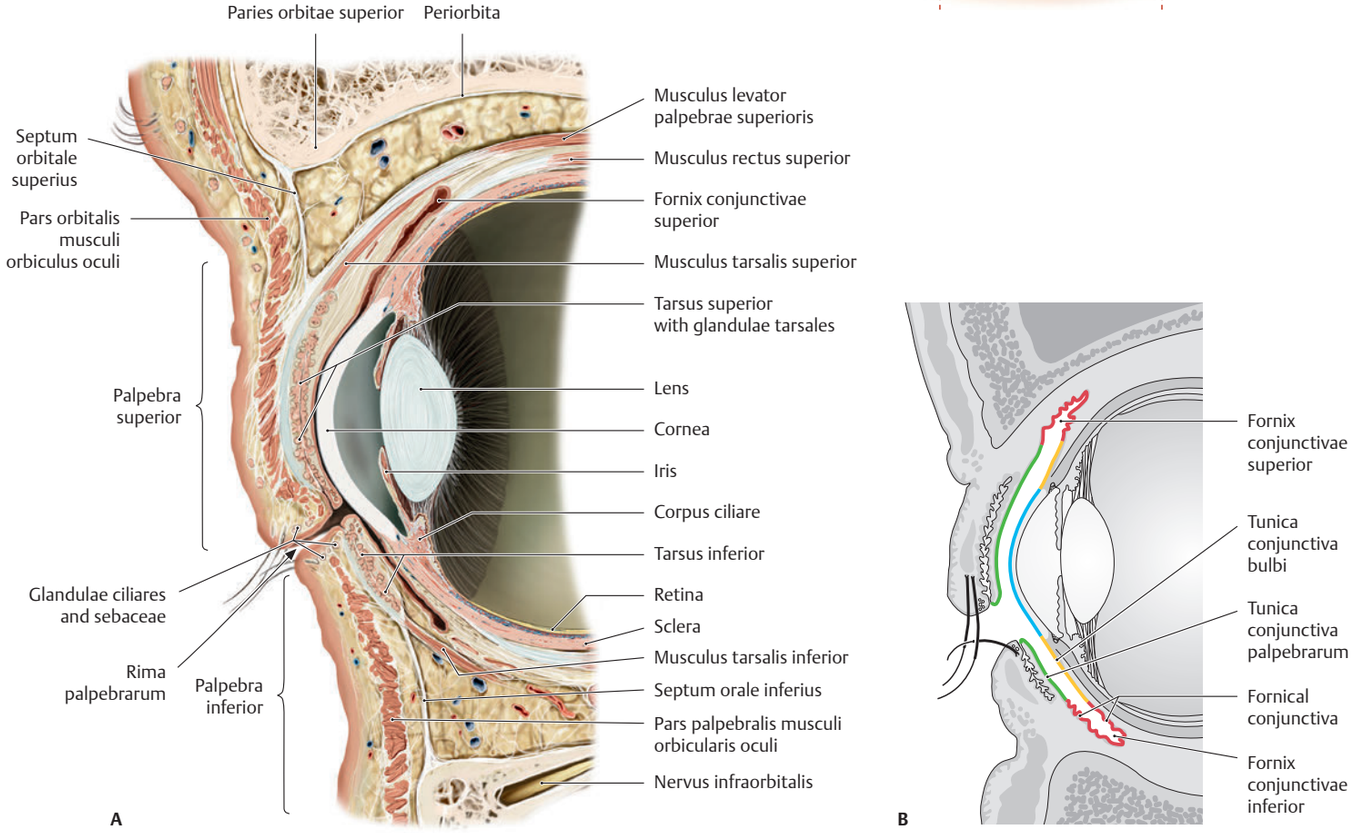


Fig. 9.20 **Structure of the palpebrae and conjunctiva**
A Sagittal section through the anterior cavitas orbitalis. **B** Anatomy of the conjunctiva.

The palpebrae consist clinically of an outer and an inner layer with the following components:

- Outer layer: palpebral skin, sweat glands, glandulae ciliares (= modified sweat glands, Moll glands), glandulae sebaceae (Zeis glands), and two striated muscles, the orbicularis oculi and levator palpebrae (upper palpebrae only), innervated by the nervus facialis and the nervus oculomotorius respectively.
- Inner layer: the tarsus (fibrous tissue plate), the musculi tarsales superior and inferior (of Müller; *smooth* muscle innervated by sympathetic fibers), the tarsal or palpebral conjunctiva, and the glandulae tarsales (meibomian glands).

Regular blinking (20 to 30 times per minute) keeps the eyes from drying out by evenly distributing the lacrimal fluid and glandular secretions. Mechanical irritants (e.g., grains of sand) evoke the *blink reflex*, which also serves to protect the cornea and **conjunctiva**. The conjunctiva tunica conjunctiva is a vascularized, thin, glistening mucous membrane that is subdivided into the *tunica conjunctiva palpebrarum* (green), *fornices conjunctivae* (red), and *tunica conjunctiva bulbi* (yellow). The tunica conjunctiva bulbi borders directly on the corneal surface and combines with it to form the **saccus conjunctivalis**, whose functions include:

- facilitating ocular movements,
- enabling painless motion of the tunica conjunctiva palpebrarum and tunica conjunctiva bulbi relative to each other (lubricated by lacrimal fluid), and
- protecting against infectious pathogens (collections of lymphocytes along the fornices).

The fornices conjunctivae superior and inferior are the sites where the tunica conjunctiva is reflected from the palpebra superior and inferior, respectively, onto the bulbus oculi. They are convenient sites for the instillation of ophthalmic medications. *Inflammation of the tunica conjunctiva* is common and causes a dilation of the conjunctival vessels resulting in "pink eye." Conversely, a deficiency of red blood cells (anemia) may lessen the prominence of vascular markings in the tunica conjunctiva. This is why the tunica conjunctiva should be routinely inspected in every clinical examination.

Apparatus Lacrimalis

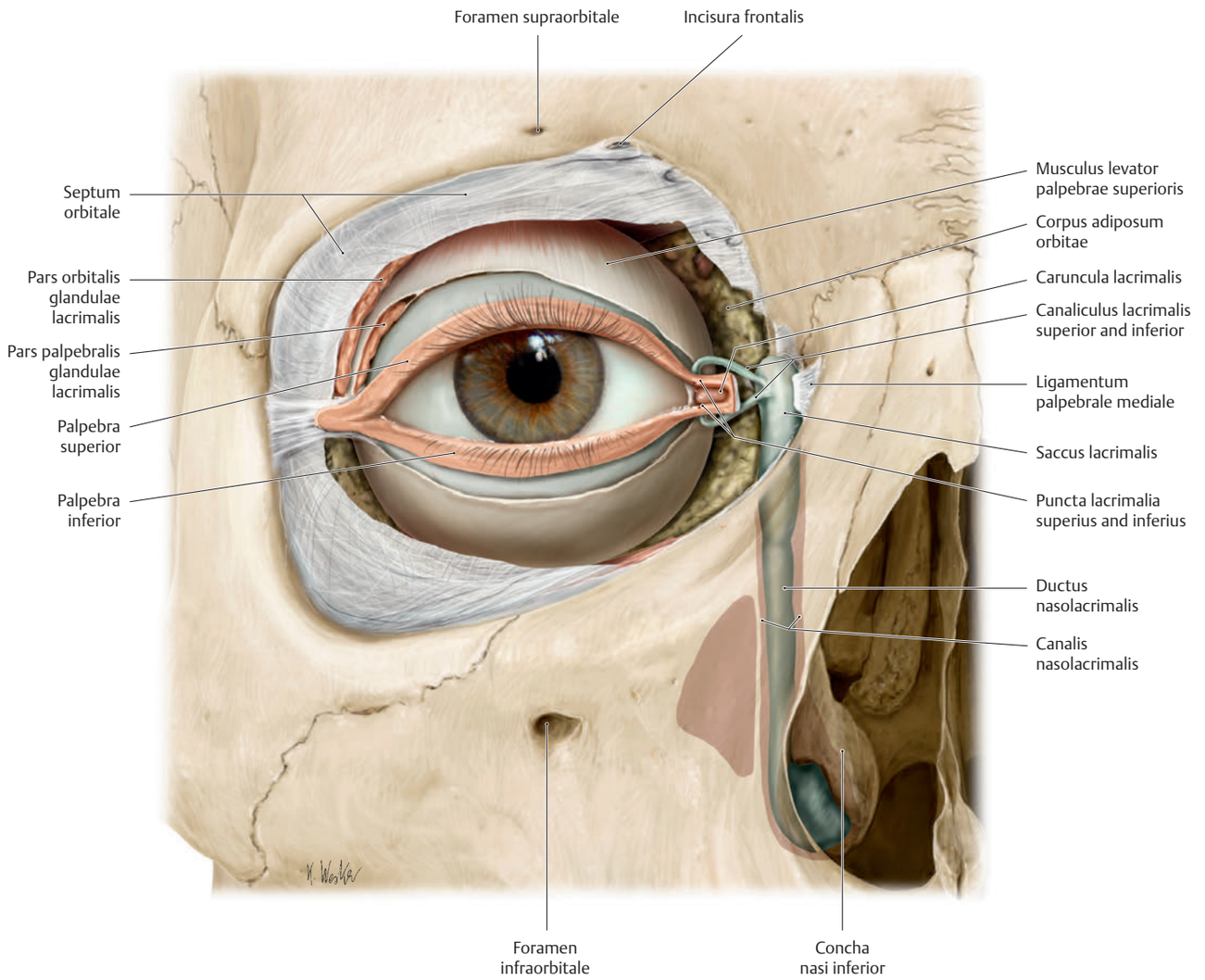


Fig. 9.21 **Apparatus lacrimalis**
Right eye, anterior view. The septum orbitale has been partially removed, and the tendon of insertion of the musculus levator palpebrae superioris has been divided. The hazelnut-sized **glandula lacrimalis** is located in the fossa glandulae lacrimalis of the os frontale and produces most of the lacrimal fluid. Smaller *glandulae lacrimales accessoriae* (Krause or Wolfring glands) are also present. The tendon of musculus levator palpebrae subdivides the glandula lacrimalis, which normally is not visible or palpable, into an *pars orbitalis* (two thirds of gland) and a *pars palpebralis* (one third). The sympathetic fibers innervating the glandula lacrimalis originate from the ganglion cervicale superius and travel along arteries to reach the glandula lacrimalis. Parasympathetic fibers reach the glandula lacrimalis via the nervus lacrimalis (CN V_1). The nervus lacrimalis communicates with the nervus zygomaticus (CN V_2), which relays postganglionic parasympathetic fibers from the ganglion pterygopalatinum. The preganglionic parasympathetic fibers that synapse in the ganglion pterygopalatinum travel as the nervus petrosus major, which arises from the genu of the nervus facialis (CN VII) (see **Fig. 4.90**). The **apparatus lacrimalis** can be understood by tracing the flow of lacrimal fluid obliquely downward from the superolateral margin of the orbita (by the glandula lacrimalis) to the inferomedial margin (see **Fig. 9.23**). From the *puncta* lacrimalia superius and inferius, the lacrimal fluid enters the superior and inferior, which direct the fluid into the *saccus lacrimalis*. Finally, it drains through the *ductus nasolacrimalis* to an outlet below the concha nasi inferior. “Watery eyes” are a typical cold symptom caused by obstruction of the inferior opening of the ductus nasolacrimalis. Dry eyes, on the other hand, is a symptom of Sjögren syndrome, an autoimmune disease causing keratoconjunctivitis sicca (diminished tear production) and xerostomia (dry mouth). It is associated with rheumatoid arthritis (in 50% of cases) and lupus. Lymphocytes and plasma cells infiltrate secretory glands and cause injury. Diminished tear production causes dry, itchy, gritty eyes, while diminshed saliva production makes swallowing difficult and increases the likelihood of development of dental caries. Rhematoid arthritis causes joint pain, swelling and stiffness.

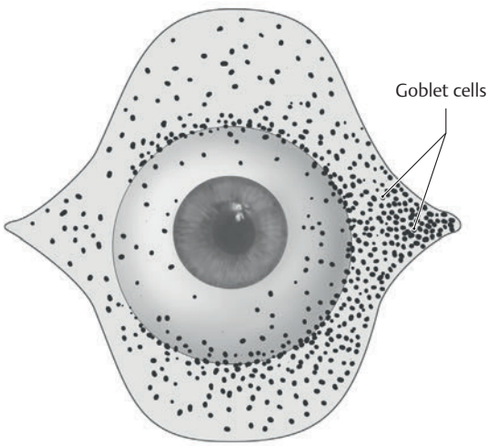


Fig. 9.22 **Distribution of goblet cells in the conjunctiva**
Goblet cells are mucus-secreting cells with an epithelial covering. Their secretions (mucins) are an important constituent of the lacrimal fluid. Mucins are also secreted by the main glandula lacrimalis.

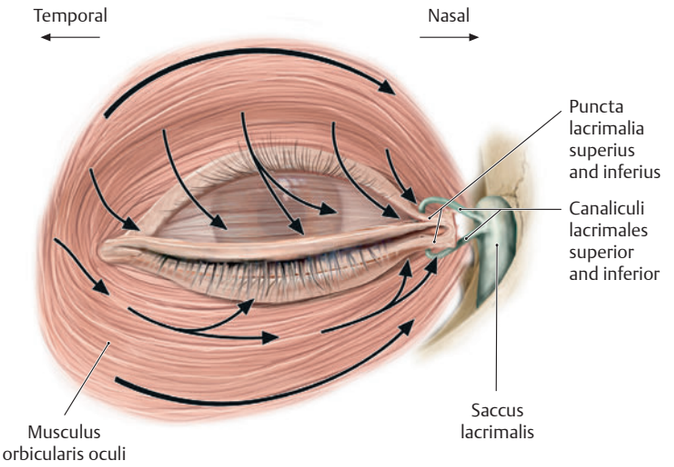


Fig. 9.23 **Mechanical propulsion of the lacrimal fluid**
During closure of the palpebrae, contraction of the musculus orbicularis oculi proceeds in a temporal-to-nasal direction. The successive contraction of these muscle fibers propels the lacrimal fluid toward the lacrimal passages. *Note:* Facial paralysis prevents closure of the palpebrae, causing the eye to dry out.

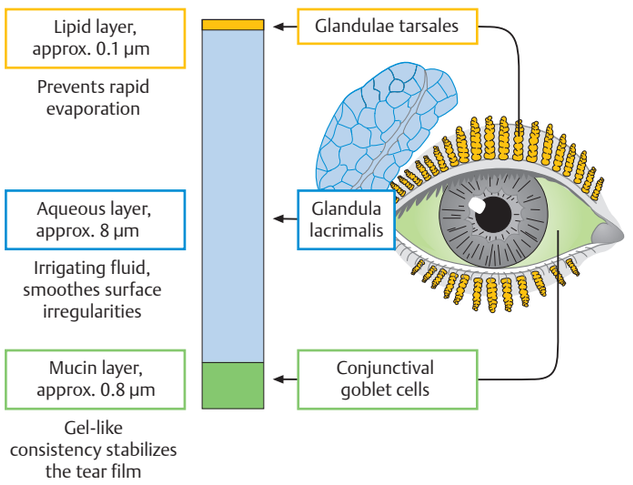


Fig. 9.24 **Structure of the tear film**
The tear film is a complex fluid with several morphologically distinct layers, whose components are produced by individual glands. The outer lipid layer, produced by the glandulae tarsales, protects the aqueous middle layer of the tear film from evaporating.

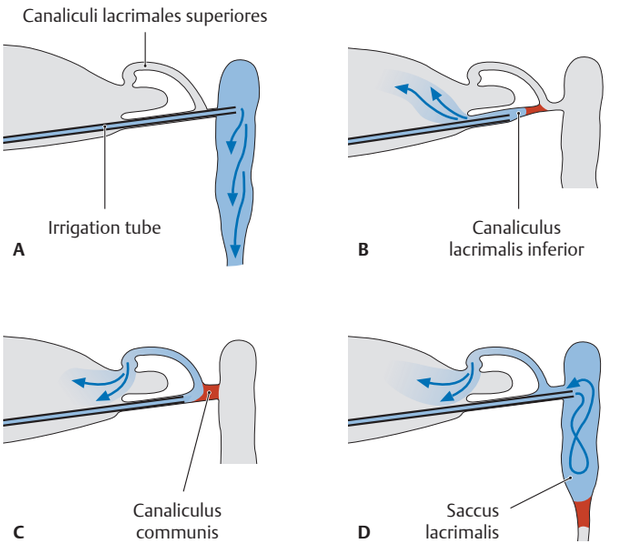


Fig. 9.25 **Obstructions to lacrimal drainage**
Sites of obstruction in the lacrimal drainage system can be located by irrigating the system with a special fluid.

A No obstruction to lacrimal drainage.
B,C Stenosis in the canaliculus lacrimalis inferior or canaliculus communis. The stenosis causes a damming back of lacrimal fluid behind the obstructed site. In **B** the fluid refluxes through the canalis lacrimalis inferior, and in **C** it flows through the canaliculus lacrimalis superior.
D Stenosis below the level of the saccus lacrimalis (postlacrimal sac stenosis). When the entire saccus lacrimalis has filled with fluid, the fluid begins to reflux into the canaliculus lacrimalis superior. In such cases, the lacrimal fluid often has a purulent, gelatinous appearance.

Bulbus Oculi

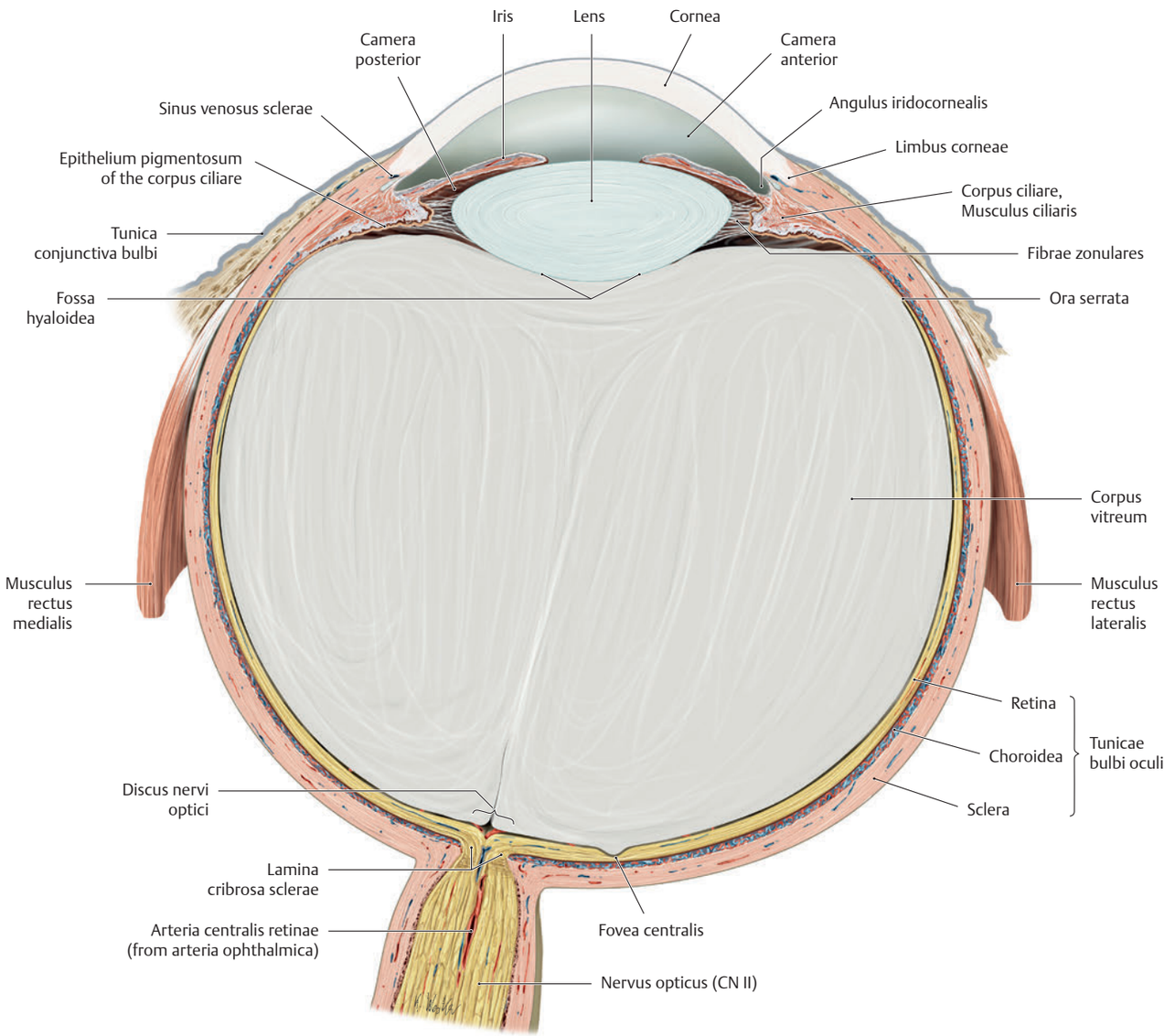


Fig. 9.26 **Bulbus oculi**
Right eye, superior view of transverse section. Most of the bulbus oculi is composed of three concentric layers surrounding humor vitreus: the sclera, the choroidea, and the retina.
Posterior portion of the bulbus oculi: The **sclera** is the posterior portion of the outer coat of the bulbus oculi. It is a firm layer of connective tissue that gives attachment to the tendons of all the extraocular muscles. The middle layer of the eye, the **choroidea**, is the most highly vascularized region in the body and serves to regulate the temperature of the eye and to supply blood to the outer layers of the retina. The inner layer of the eye, the **retina**, includes an inner layer of photosensitive cells (sensory retina) and an outer layer of retinal pigment epithelium. The axons of the nervus opticus (CN II) pierce the lamina cribrosa sclerae at the discus nervi optici. The *fovea centralis* is a depressed area in the central retina approximately 4 mm temporal to the optic disk. Incident light is normally focused on the fovea centralis, the site of greatest visual acuity.
Anterior portion: The anterior portion of the bulbus oculi has a different structure that is continuous with the posterior portion. The outer fibrous coat is the cornea, the "window of the eye," which bulges forward. At the limbus corneae, the cornea is continuous with the less convex sclera. In the angulus iridiocornealis of the camera anterior, the sclera forms the reticulum trabeculare, which is connected to the sinus venosus sclerae. Beneath the sclera is the tunica vasculosa bulbi, also called the uveal tract. It consists of three parts: the iris, corpus ciliare, and choroidea. The iris shields the eye from excessive light and covers the lens. Its root is continuous with the corpus ciliare, which contains the musculus ciliaris for visual accommodation (alters the refractive power of the lens). The epithelium of the corpus ciliare produces the humor aquosus. The corpus ciliare is continuous at the ora serrata with the choroidea. The outer layer of the retina (stratum pigmentosum) is continued forward as the epithelium pigmentosum of the corpus ciliare and the epithelium of the iris.
Bulbus oculi rupture involves a full-thickness defect in the cornea and/or sclera. It may occur following penetrating or blunt trauma. It is a true ophthalmologic emergency that requires prompt surgical repair to prevent permanent loss of vision or poor eye functionality.

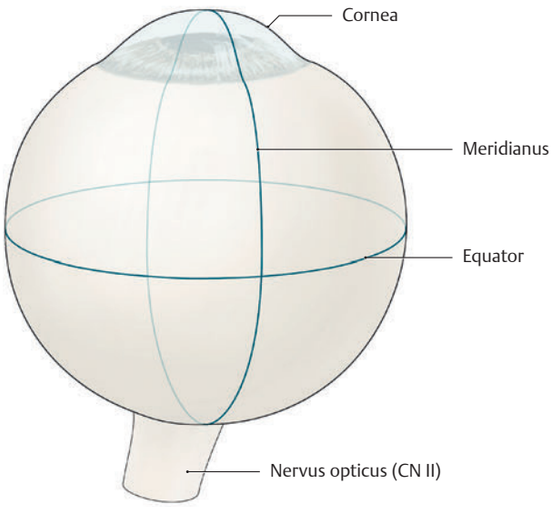


Fig. 9.27 **Reference lines and points on the eye**
The line marking the greatest circumference of the bulbus oculi is the *equator.* Lines perpendicular to the equator are called *meridiani.*

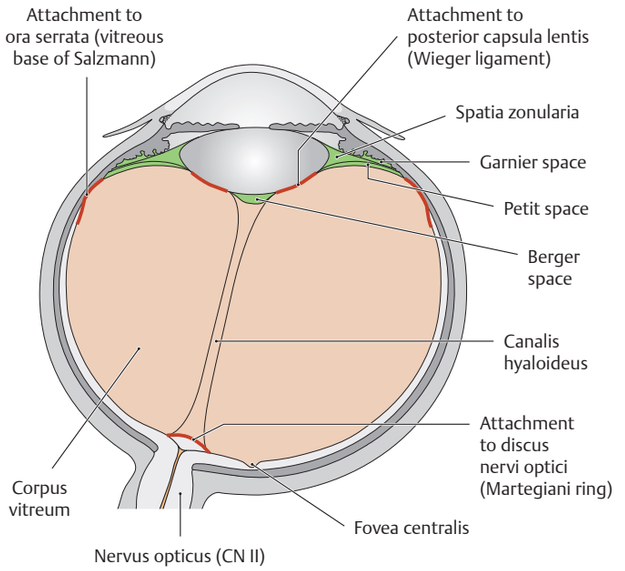


Fig. 9.28 **Corpus vitreum (humor vitreus)**
Right eye, transverse section, superior view. Sites where the corpus vitreum is attached to other ocular structures are shown in red, and adjacent spaces are shown in green. The corpus vitreum stabilizes the bulbus oculi and protects against retinal detachment. Devoid of nerves and vessels, it consists of 98% water and 2% hyaluronic acid and collagen. The "canalis hyaloideus" is an embryological remnant of the arteria hyaloidea. For the treatment of some diseases, the corpus vitreum may be surgically removed (vitrectomy) and the resulting cavity filled with physiological saline solution.

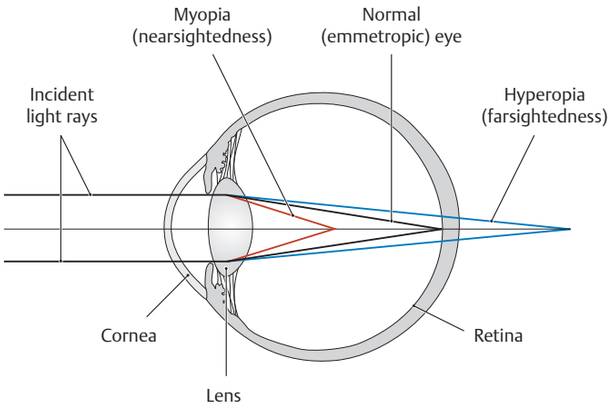


Fig. 9.29 **Light refraction**
In a normal (emmetropic) eye, parallel rays from a distant light source are refracted by the cornea and lens to a focal point on the retinal surface.

- In myopia (nearsightedness), the rays are focused to a point *in front* of the retina.
- In hyperopia (farsightedness), the rays are focused *behind* the retina.
- In astigmatism (asymmetrical lens curvature in the horizontal and vertical axes) some rays are focused in front of the retina and some behind.

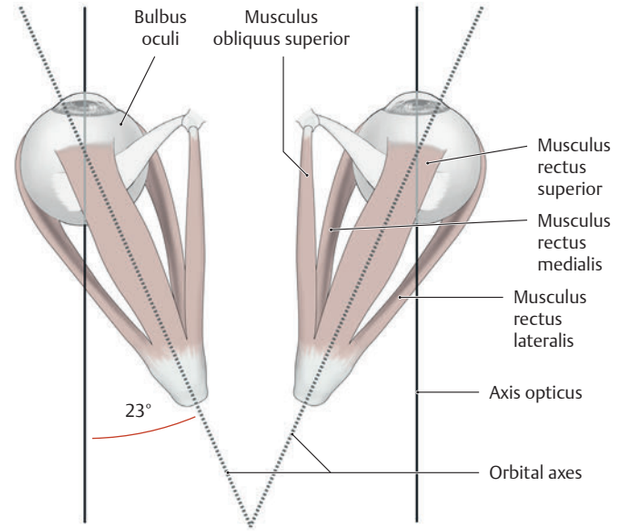


Fig. 9.30 **Axis opticus and orbital axis**
Superior view of both eyes showing the musculi recti medialis, lateralis, and superior and the musculus obliquus superior. The axis opticus deviates from the orbital axis by 23 degrees. Because of this disparity, the point of maximum visual acuity, the fovea centralis, is lateral to the "blind spot" of the discus opticus.

Eye: Blood Supply

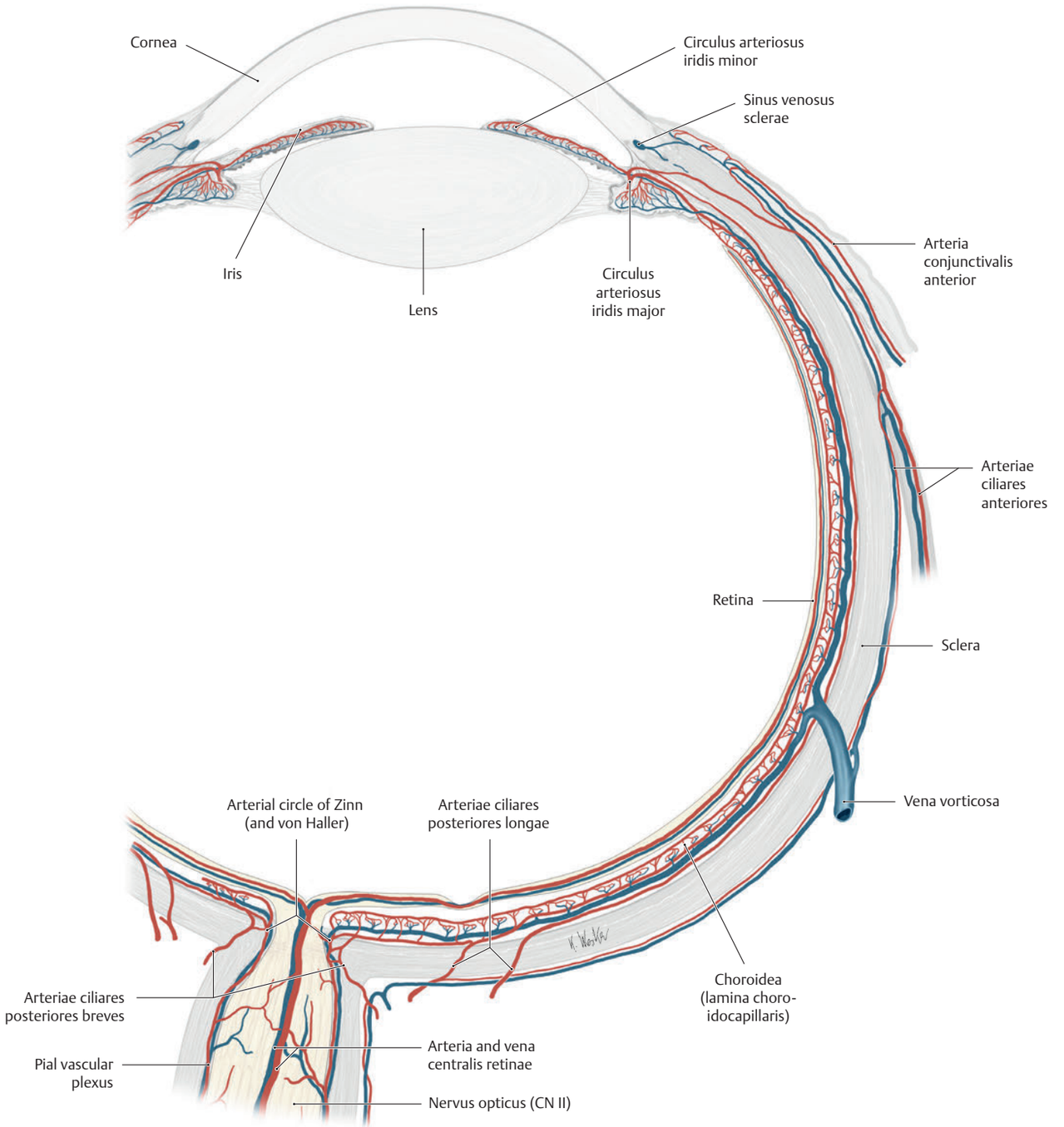


Fig. 9.31 **Blood supply of the eye**
Transverse section through the right eye at the level of the nervus opticus, superior view. All of the arteries that supply the eye arise from the *arteria ophthalmica,* a branch of the arteria carotis interna. Its ocular branches are:

- Arteria centralis retinae to the retina
- Arteriae ciliares posteriores breves to the choroidea
- Arteriae ciliares posteriores longae to the corpus ciliare and iris, where they supply the circuli arteriosi iridis major and minor (see **Fig. 9.41**)
- Arteriae ciliares anteriores, which arise from the vessels of the rectus muscles of the eye and anastomose with the arteriae ciliares posteriores

Blood is drained from the bulbus oculi by four to eight venae vorticosae, which pierce the sclera behind the equator and open into the vena ophthalmica superior or inferior.
The vena ophthalmica superior communicates with the sinus cavernosus via the fissura orbitalis superior; the vena ophthalmica inferior communicates posteriorly with the plexus pterygoideus of veins via the fissura orbitalis inferior and with the sinus cavernosus.

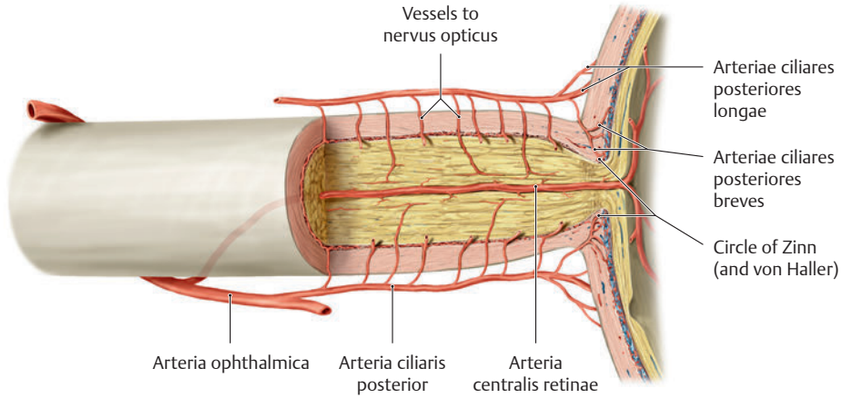
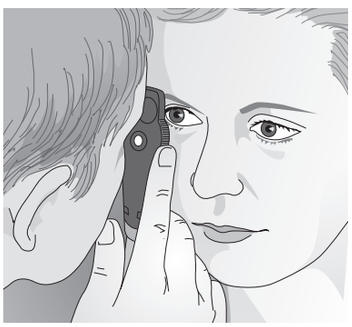
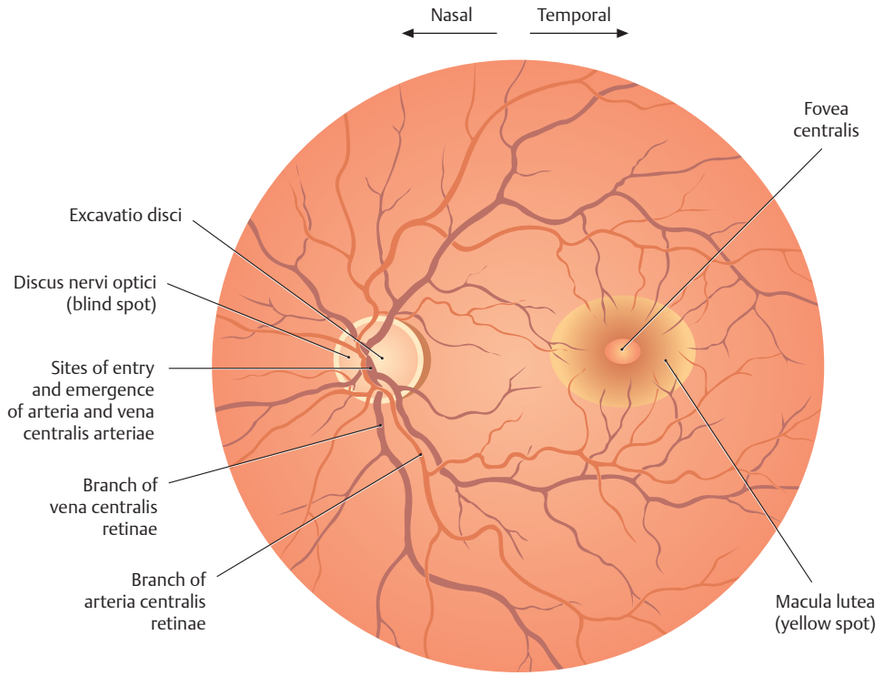


Fig. 9.32 **Arteries of the nervus opticus (CN II)**
Lateral view. The arteria centralis retinae, the first branch of the arteria ophthalmica, enters the nervus opticus from below approximately 1 cm behind the bulbus oculi and courses with it to the retina while giving off multiple small branches. The arteria ciliaris posterior also gives off several small branches that supply the nervus opticus. The distal part of the nervus opticus receives its arterial blood supply from an arterial ring (circle of Zinn and von Haller) formed by anastomoses among the side branches of the arteriae ciliares posteriores breves and arteria centralis retinae.



A



B

Fig. 9.33 **Ophthalmoscopic examination of the optic fundus**
A Examination technique (direct ophthalmoscopy). **B** Normal appearance of the optic fundus.
In direct ophthalmoscopy, the following structures of the optic fundus can be directly evaluated at approximately 16 x magnification:

- The condition of the retina
- The blood vessels (particularly the arteria centralis retinae)
- The discus nervi optici (where the nervus opticus emerges from the bulbus oculi)
- The macula lutea and fovea centralis

Because the retina is transparent, the color of the optic fundus is determined chiefly by the stratum pigmentosum and the blood vessels of the choroidea. It is uniformly pale red in light-skinned persons and is considerably browner in dark-skinned persons. Abnormal detachment of the retina is usually associated with a loss of retinal transparency, and the retina assumes a yellowish white color. The arteria and vena centralis retinae can be distinguished from each other by their color and caliber: arteries have a brighter red color and a smaller caliber than the veins. This provides a means for the early detection of vascular changes (e.g., stenosis, wall thickening, microaneurysms), such as those occurring in diabetes mellitus (diabetic retinopathy) or hypertension. The *discus nervi optici* normally has sharp margins, a yellow-orange color, and a central depression, the excavatio disci. The disk is subject to changes in pathological conditions such as elevated intracranial pressure (papilledema with ill-defined disk margins). On examination of the *macula lutea*, which is 3 to 4 mm temporal to the optic disk, it can be seen that numerous branches of the arteria centralis retinae radiate toward the macula but do not reach its center, the fovea centralis (the fovea receives its blood supply from the choroidea). A common age-related disease of the macula lutea is macular degeneration. It is caused by the buildup of yellow deposits, or drusen, on the macula that damages the rods and cones. Symptoms are insidious and may affect one or both eyes. They include blurriness or loss of central vision, which may manifest as difficulty reading and difficulty recognizing faces, decreased color intensity, and decreased adaptation to dark environments.

Eye: Lens & Cornea

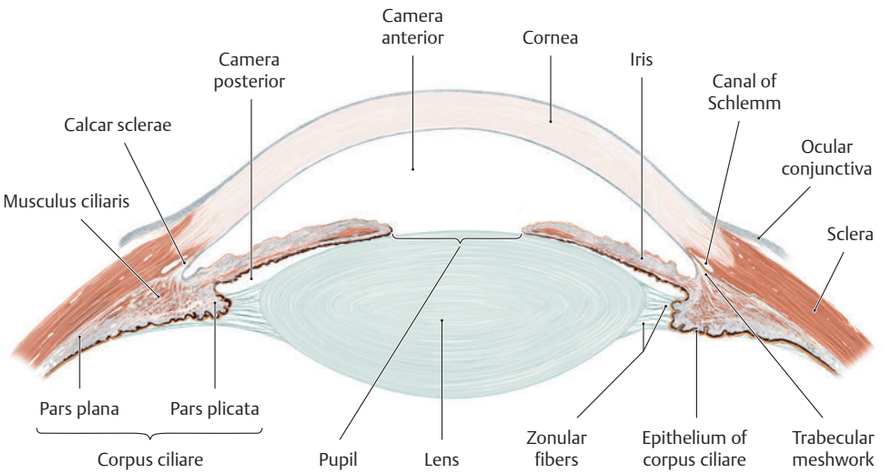


Fig. 9.34 **Position of the lens and cornea**
Transverse section through the cornea, lens, and suspensory apparatus of the lens. The normal lens is clear, transparent, and only 4 mm thick. It is suspended in the fossa hyoidea of the corpus vitreum. The lens is attached by rows of fibrils (fibrae zonulares) to the musculus ciliaris, whose contractions alter the shape and focal length of the lens. Thus, the lens is a dynamic structure that can change its shape in response to visual requirements. The camera anterior of the eye is situated in front of the lens, and the camera posterior is located between the iris and the anterior epithelium of the lens. The lens, like the corpus vitreum, is devoid of nerves and blood vessels and is composed of elongated epithelial cells (lens fibers).

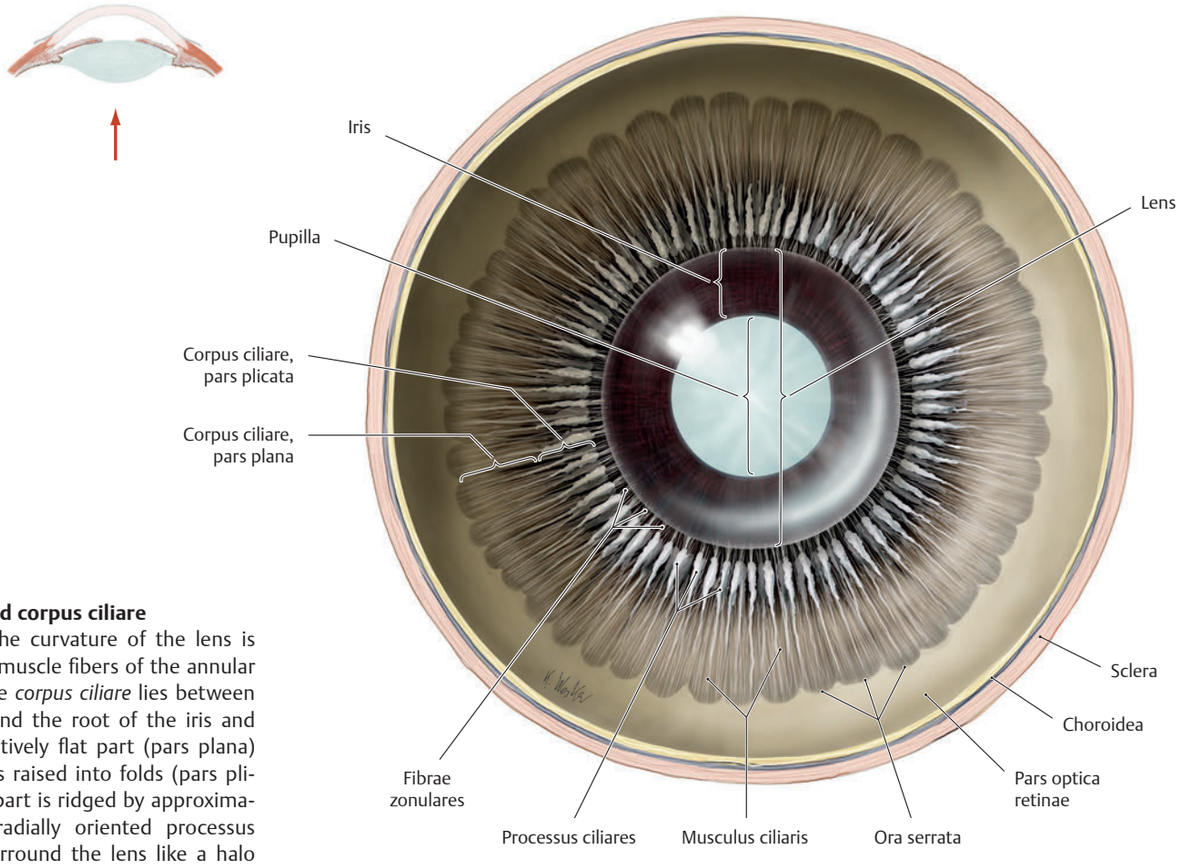


Fig. 9.35 **Lens and corpus ciliare**
Posterior view. The curvature of the lens is regulated by the muscle fibers of the annular corpus ciliare. The *corpus ciliare* lies between the ora serrata and the root of the iris and consists of a relatively flat part (pars plana) and a part that is raised into folds (pars plicata). The latter part is ridged by approximately 70 to 80 radially oriented processus ciliares, which surround the lens like a halo when viewed from behind. The processus ciliares contain large capillaries, and their epithelium secretes the humor aquosus. Very fine *fibrae zonulares* extend from the basal layer of the processus ciliares to the equator of the lens. These fibers and the spaces between them constitute the suspensory apparatus of the lens, called the *zonula ciliaris*. Most of the corpus ciliare is occupied by the musculus ciliaris, a smooth muscle composed of meridional, radial, and circular fibers. It arises mainly from the calcar sclerae (a reinforcing ring of sclera just below the sinus venosus sclerae), and it attaches to structures including the lamina basalis of the choroidea and the inner surface of the sclera. When the musculus ciliaris contracts, it pulls the choroidea forward and relaxes the fibrae zonulares. As these fibers become lax, the intrinsic resilience of the lens causes it to assume the more convex relaxed shape that is necessary for near vision. This is the basic mechanism of visual accommodation.

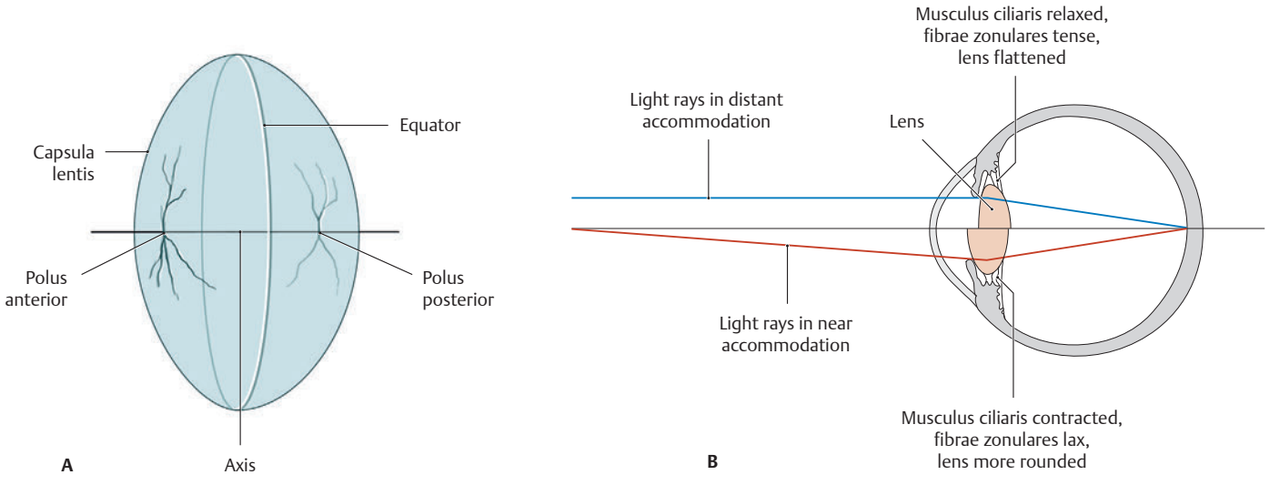


Fig. 9.36 **Reference lines and dynamics, oblique lateral view of the lens**

A Principal reference lines of the lens: The lens has polus *anterior* and a *polus posterior*, an *axis* passing between the poles, and an *equator*. The lens has a biconvex shape with a greater radius of curvature posteriorly (16 mm) than anteriorly (10 mm). Its function is to transmit light rays and make fine adjustments in refraction. Its refractive power ranges from 10 to 20 diopters, depending on the state of accommodation. The cornea has a considerably higher refractive power of 43 diopters.

B Light refraction and dynamics of the lens, sagittal section:

- Upper half of diagram: fine adjustment of the eye for *far vision*. Parallel light rays arrive from a distant source, and the lens is flattened.
- Lower half of diagram: For *near vision* (accommodation to objects less than 5 m from the eye), the lens assumes a more rounded shape. This is effected by contraction of the musculus ciliaris (parasympathetic innervation from the nervus oculomotorius), causing the fibrae zonulares to relax and allowing the lens to assume a more rounded shape because of its intrinsic resilience.

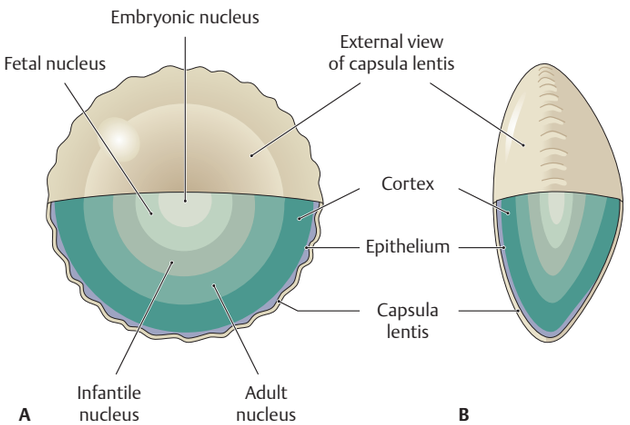


Fig. 9.37 **Growth of the lens and zones of discontinuity**

A Anterior view. **B** Lateral view.

The lens continues to grow throughout life, doing so in a manner opposite to that of other epithelial structures (i.e., the youngest cells are at the surface of the lens, whereas the oldest cells are deeper). Due to the constant proliferation of epithelial cells, which are all firmly incorporated in the lens capsule, the tissue of the lens becomes increasingly dense with age. A slit-lamp examination will demonstrate zones of varying cell density (zones of discontinuity). The zone of highest cell density, the *embryonic nucleus*, is at the center of the lens. With further growth, it becomes surrounded by the *fetal nucleus*. The *infantile nucleus* develops after birth, and finally the *adult nucleus* begins to form during the third decade of life. These zones are the basis for the morphological classification of cataracts, a structural alteration in the lens or its capsule, causing opacity, that is more or less normal in old age (present in 10% of all 80-year-olds). It produces blurred, cloudy vision.

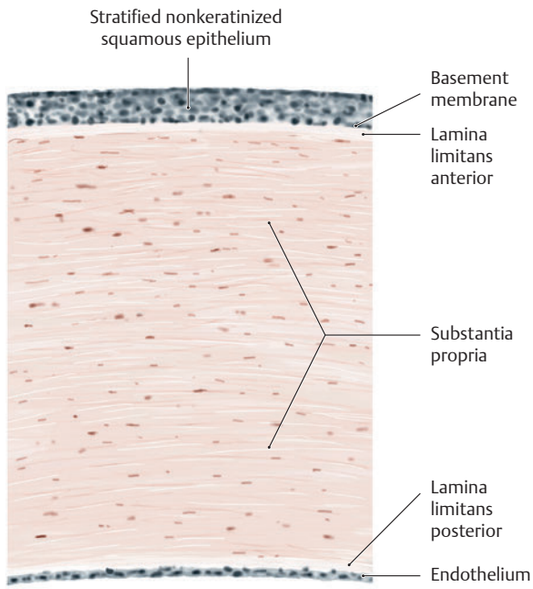


Fig. 9.38 **Structure of the cornea**

The cornea is covered externally by stratified, nonkeratinized squamous epithelium whose basal lamina borders on the lamina limitans anterior (Bowman membrane). The stroma (substantia propria) makes up approximately 90% of the corneal thickness and is bounded on its deep surface by the lamina limitans posterior (Descemet membrane). Beneath is a single layer of corneal endothelium. The cornea does have a nerve supply (for corneal reflexes), but it is not vascularized and therefore has an immunologically privileged status: normally, a corneal transplant can be performed without fear of a host rejection response.

Eye: Iris & Ocular Chambers

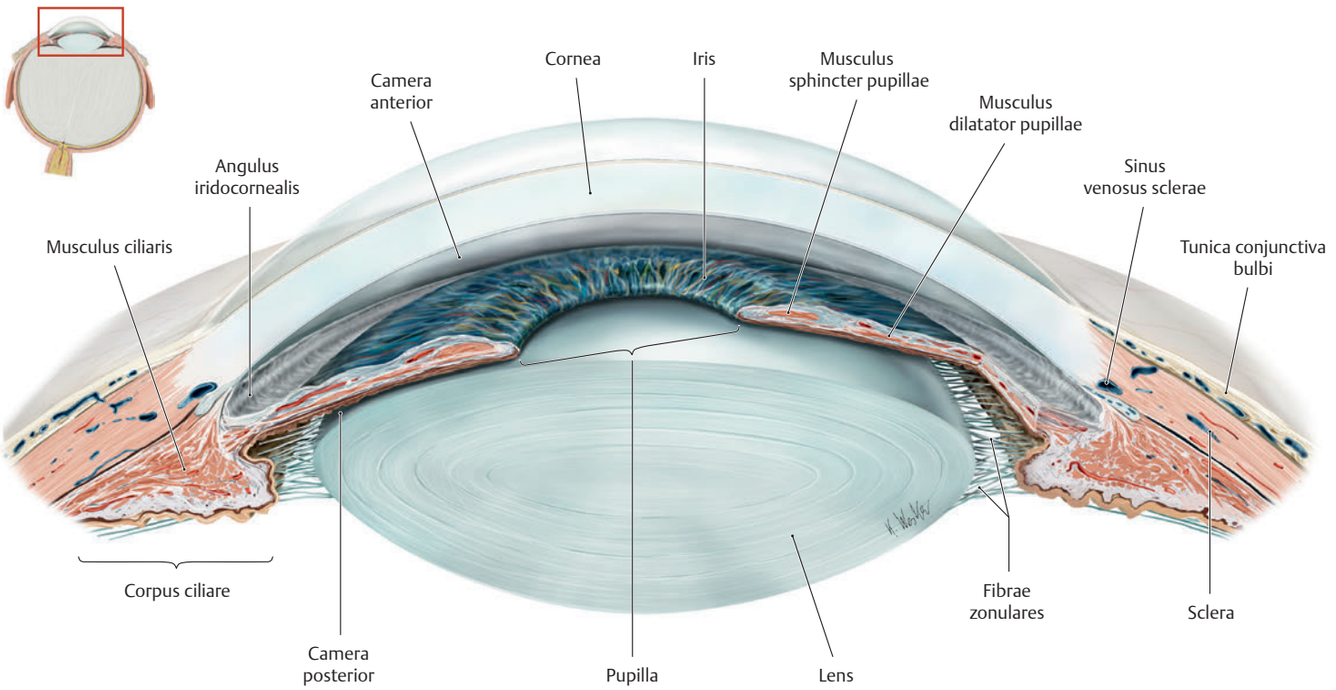


Fig. 9.39 **Iris and chambers of the eye**
Transverse section through the segmentum anterius of the eye, superior view. The iris, the choroidea, and the corpus ciliare at the periphery of the iris are part of the uveal tract. In the iris, the pigments are formed that determine eye color. The iris is an optical diaphragm with a central aperture, the pupilla, placed in front of the lens. The pupilla is 1 to 8 mm in diameter; it constricts on contraction of the musculus sphincter pupillae (*parasympathetic* innervation via the nervus oculomotorius and ganglion ciliare) and dilates on contraction of the musculus dilatator pupillae (*sympathetic* innervation from the ganglion cervicale superius via the plexus caroticus internus). Together, the iris and lens separate the camera anterior of the eye from the camera posterior. The camera posterior behind the iris is bounded posteriorly by the corpus vitreum, centrally by the lens, and laterally by the corpus ciliare. The camera anterior is bounded anteriorly by the cornea and posteriorly by the iris and lens.

Fig. 9.40 **Pupilla size**
A Normal pupilla size. **B** Maximum constriction (miosis). **C** Maximum dilation (mydriasis).
The regulation of pupilla size is aided by the two intraocular muscles, the musculus sphincter pupillae and musculus dilatator pupillae. The musculus sphincter pupillae (parasympathetic innervation) narrows the pupilla, and the musculus dilatator pupillae (sympathetic innervation) enlarges the pupilla. Pupilla size is normally adjusted in response to incident light and serves mainly to optimize visual acuity. Normally, the pupillae are circular in shape and equal in size (3 to 5 mm). Various influences may cause the pupilla size to vary over a range from 1.5 mm (miosis) to 8 mm (mydriasis). A greater than 1 mm discrepancy of pupil size between the right and left eyes is called *anisocoria*. Mild anisocoria is physiological in some individuals. Pupillary reflexes such as convergence and the consensual light response are described on pp. 258 and 259.

Table 9.5 **Changes in pupilla size: causes**

Pupilla constriction (parasympathetic)	Pupilla dilation (sympathetic)
Light	Darkness
Sleep, fatigue	Pain, excitement
Miotic agents: • Parasympathomimetics (e.g., tear gas, VX and sarin, Alzheimer's drugs such as rivastigmine) • Sympatholytics (e.g., antihypertensives)	Mydriatic agents: • Parasympatholytics (e.g., atropine) • Sympathomimetics (e.g., epinephrine)
Horner syndrome (also causes ptosis and narrowing of palpebral fissure)	Oculomotor palsy
General anesthesia, morphine	Migraine attack, glaucoma attack

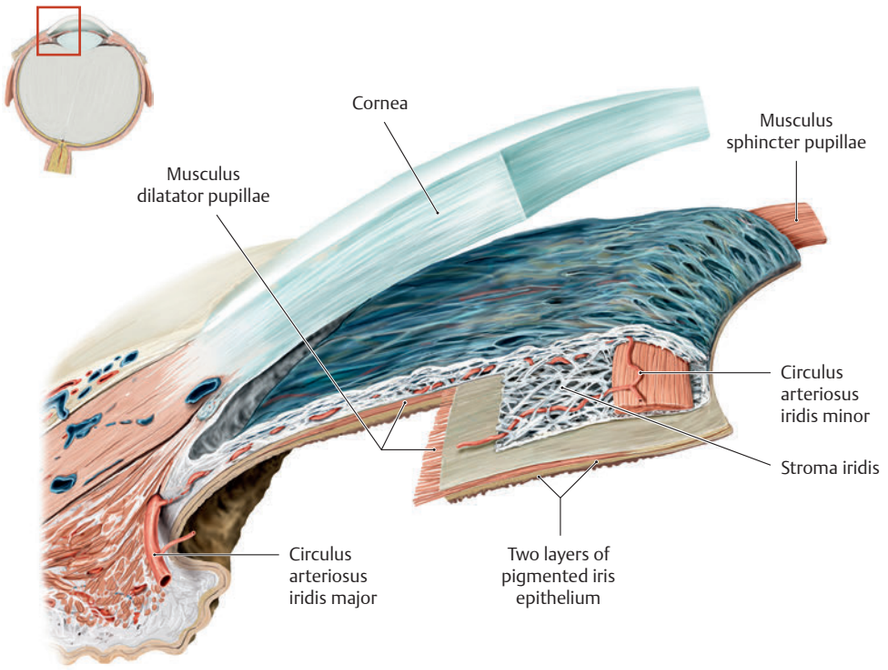


***Fig. 9.41* Structure of the iris**
Transverse and parasagittal section, superior view. The basic structural framework of the iris is the vascularized stroma iridis, which is bounded on its deep surface by two layers of epithelium pigmentosum. The loose, collagen-containing stroma of the iris contains outer and inner vascular circles (circuli arteriosi iridis major and minor), which are interconnected by small anastomotic arteries. The musculus sphincter pupillae is an annular muscle located in the stroma iridis bordering the pupil. The radially disposed musculus dilatator pupillae is not located in the stroma iridis; rather, it is composed of numerous myofibrils in the iris epithelium (myoepithelium). The stroma iridis is permeated by pigmented connective tissue cells (melanocytes). When heavily pigmented, these melanocytes of the anterior border zone of the stroma iridis render the iris brown or "black." Otherwise, the characteristics of the underlying stroma iridis and epithelium determine eye color, in a manner that is not fully understood.

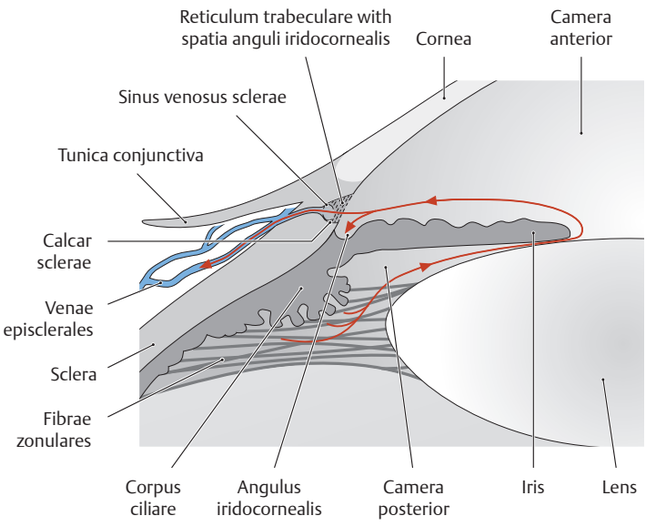


***Fig. 9.42* Normal drainage of humor aquosus**
The humor aquosus (approximately 0.3 mL per eye) is an important determinant of the intraocular pressure. It is produced by the nonpigmented ciliary epithelium of the processus ciliares in the camera *posterior* (approximately 0.15 mL/hour) and passes through the pupil into the camera *anterior* of the eye. The humor aquosus seeps through the spaces of the reticulum trabeculare (Fontana spaces) in the angulus iridocornealis and enters the canal of Schlemm (sinus venosus sclerae), through which it drains to the venae episclerales. The draining humor aquosus flows toward the angulus iridocornealis along a pressure gradient (intraocular pressure = 15 mm Hg, pressure in the venae episclerales = 9 mm Hg) and must surmount a physiological resistance at two sites:

- *Pupillary resistance* (between the iris and lens)
- *Trabecular resistance* (narrow spaces in the reticulum trabeculare)

Approximately 85% of the humor aquosus flows through the reticulum trabeculare into the sinus venosus sclerae. Only 15% drains through the uveoscleral vascular system into the venae vorticosae (uveoscleral drainage route).

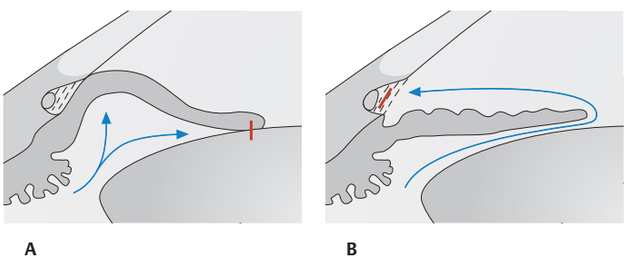


***Fig. 9.43* Obstruction of aqueous drainage and glaucoma**
Normal function of the optical system requires normal intraocular pressure (15 mm Hg in adults). This maintains a smooth curvature of the corneal surface and helps keep the photoreceptor cells in contact with the stratum pigmentosum. Obstruction of the normal drainage of humor aquosus causes an increase in intraocular pressure. This constricts the nervus opticus at the lamina cribrosa, where it emerges from the bulbus oculi through the sclera. Such constriction eventually leads to blindness. There are two types of glaucoma:

A Acute (closed-angle) glaucoma: The angulus iridocornealis is obstructed by iris tissue. Humor aquosus cannot drain into the camera anterior and pushes portions of the iris upward, blocking the angulus iridocornealis. This type of glaucoma often develops quickly.
B Chronic (open-angle) glaucoma: The angulus iridocornealis is open, but drainage through the reticulum trabeculare is impaired. Ninety percent of all glaucomas are primary chronic open-angle glaucomas. This is increasingly prevalent after 40 years of age. Treatment options include parasympathomimetics (to induce sustained contraction of the musculus ciliaris and musculus sphincter pupillae), prostaglandin analogues (to improve aqueous drainage), and beta-adrenoceptor agonists (to decrease production of humor aquosus).

Eye: Retina

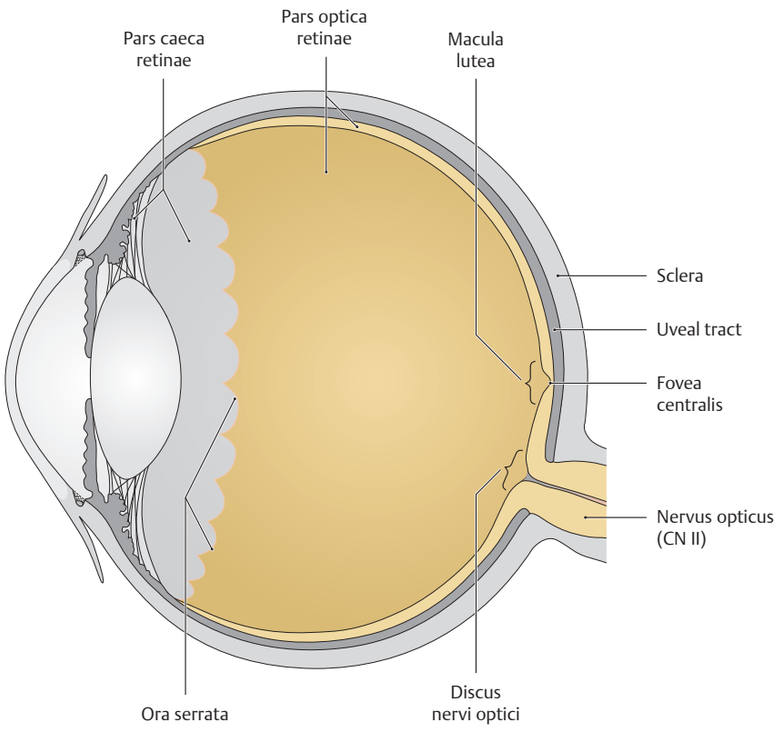


Fig. 9.44 **Overview of the retina**
Sagittal section. The retina is the third, innermost layer of the bulbus oculi. It consists mainly of a photosensitive *pars optica* retinae and a smaller, nonphotosensitive forward prolongation called the *pars caeca retinae*. The pars optica retinae (yellow) varies in thickness. It overlies the stratum pigmentosum of the uveal tract and is pressed against it by the intraocular pressure. The pars optica retinae ends at a jagged margin, the ora serrata, which is where the pars caeca retinae begins. The site on the retina where visual acuity is highest is the *fovea centralis*, a small depression at the center of a yellowish area, the *macula lutea*. The pars optica retinae is particularly thin at this site; it is thickest at the point where the nervus opticus emerges from the bulbus oculi at the lamina cribrosa.

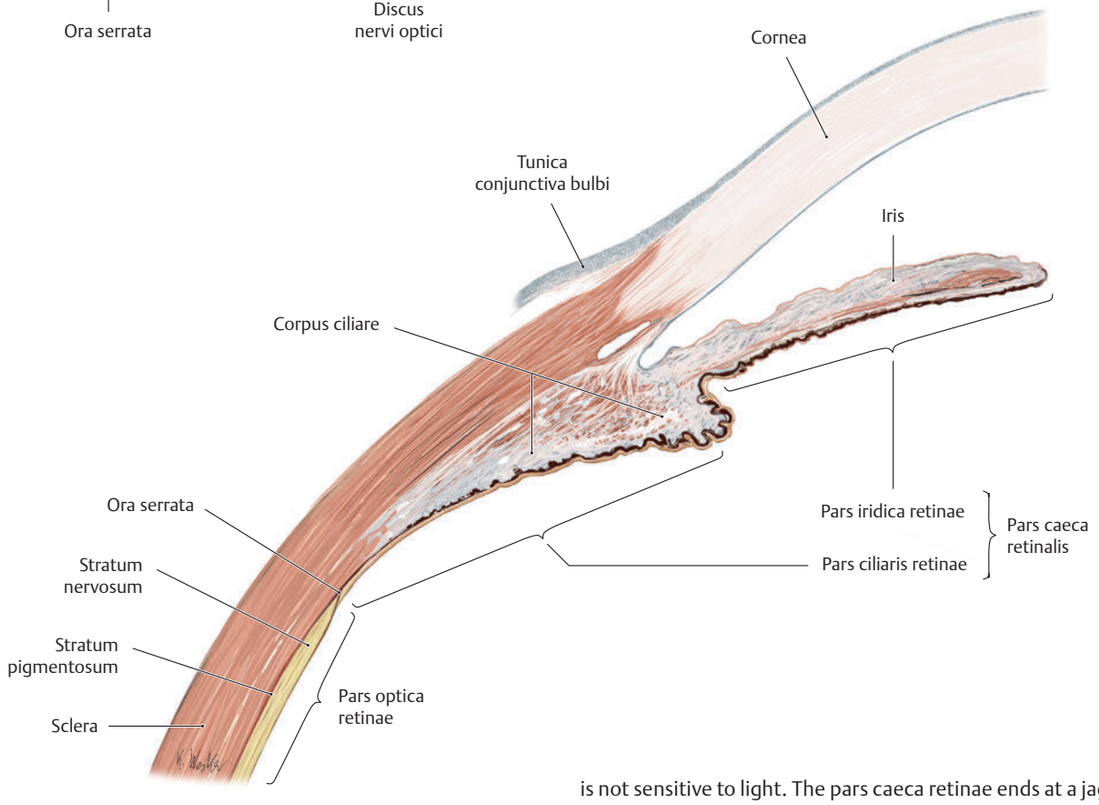


Fig. 9.45 **Parts of the retina**
Transverse section, superior view. The posterior surface of the iris bears a double layer of pigment epithelium, the *pars iridica* retinae. Just peripheral to it is the *pars ciliaris* retinae, also formed by a *double* layer of epithelium (one of which is pigmented) and covering the posterior surface of the corpus ciliare. The partes iridica and ciliaris of the retina together constitute the *pars caeca retinae*—the portion of the retina that is not sensitive to light. The pars caeca retinae ends at a jagged line, the ora serrata, where the light-sensitive *pars optica* retinae begins. Consistent with the development of the retina from the embryonic optic cup, two layers can be distinguished within the optic part:

- An outer layer nearer the sclera: the *stratum pigmentosum*, consisting of a single layer of pigmented retinal epithelium.
- An inner layer nearer the corpus vitreum: the *stratum nervosum*, comprising a system of receptor cells, interneurons, and ganglion cells.

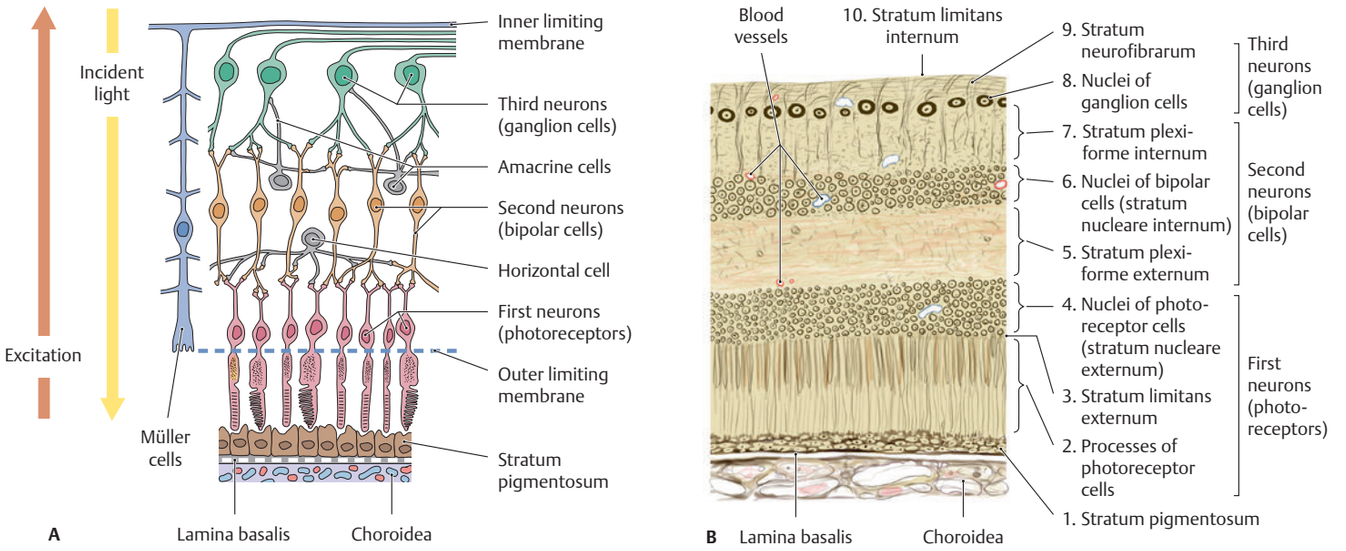


Fig. 9.46 **Structure of the retina**
A Retinal neurons of the visual pathway. **B** Anatomical layers of the retina. Light passes through all the layers of the retina to be received by the photoreceptors on the outermost surface of the retina. Sensory information is then transmitted via three retinal neurons of the visual pathway to the discus nervi optici:

- First neurons (pink): Photoreceptor cells (light-sensitive sensory cells) that transform light stimuli (photons) into electrochemical signals. The two types of photoreceptors are rods and cones, named for the shape of their receptor segment. The retina contains 100 million to 125 million rods, which are responsible for twilight and night vision, but only about 6 million to 7 million cones. Different cones are specialized for the perception of red, green, and blue. The processes and nuclei of the first neurons compose anatomical layers 2 to 4 (see **B**).
- Second neurons (yellow): Bipolar cells that receive impulses from the photoreceptors and relay them to the ganglion cells. These neurons compose anatomical layers 5 to 7.
- Third neurons (green): Retinal ganglion cells whose axons converge at the discus nervi optici to form the nervus opticus (CN II) and reach the corpus geniculatum laterale and colliculus superior. These neurons compose anatomical layers 8 to 10. There are approximately 1 million retinal ganglion axons per eye.

Support cells: Müller cells (blue) are glial cells that span the stratum nervosum radially from the stratum limitans interna to the stratum limitans externa, creating a supporting framework for the neurons. In addition to the vertical connections, horizontal and amacrine cells (gray) function as interneurons that establish lateral connections. Impulses transmitted by the receptor cells are thereby processed and organized within the retina (signal convergence).
Stratum pigmentosum: The outer layer of the retina (the stratum pigmentosum, brown) is attached to the lamina basalis, which contains elastic fibers and collagen fibrils and mediates the exchange of substances between the adjacent choroidea (lamina choroidocapillaris) and the photoreceptor cells. *Note:* The photoreceptors are in contact with the stratum pigmentosum but are not attached to it. The retina may become detached (if untreated, this leads to blindness).

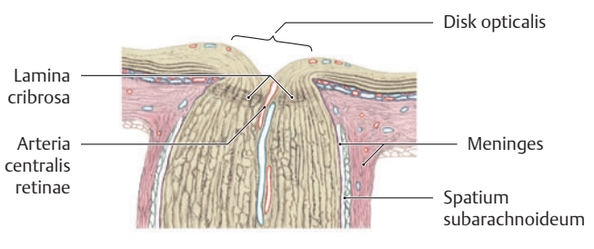


Fig. 9.47 **Discus nervi optici ("blind spot") and lamina cribrosa**
The unmyelinated axons of the third neurons (retinal ganglion cells) pass to a collecting point at the polus posterior of the eye. There they unite to form the nervus opticus and leave the retina through numerous perforations in the sclera (lamina cribrosa). (*Note:* The discus nervi optici has no photoreceptors and is therefore the physiological blind spot.) In the nervus opticus, these axons are myelinated by oligodendrocytes. The nervus opticus (CN II) is an extension of the diencephalon and therefore has all the coverings of the brain (dura mater, arachnoidea mater, and pia mater). It is surrounded by a spatium subarachnoideum that contains liquor cerebrospinalis (CSF) and communicates with the spatia subarachnoidea of the brain and medulla spinalis.

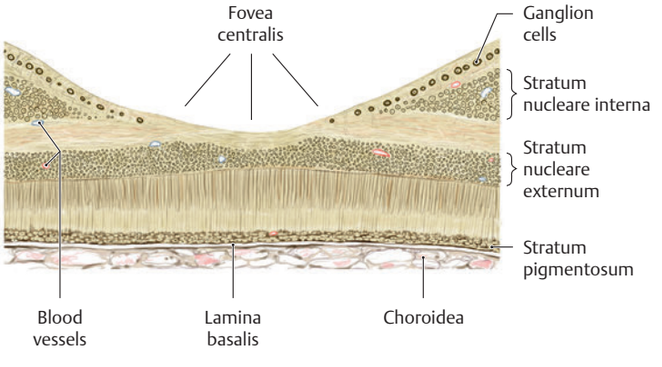


Fig. 9.48 **Macula lutea and fovea centralis**
Temporal to the discus nervi optici is the macula lutea. At its center is a funnel-shaped depression approximately 1.5 mm in diameter, the fovea centralis, which is the site of maximum visual acuity. At this site the inner retinal layers are heaped toward the margin of the depression, so that the cells of the photoreceptors (just cones, no rods) are directly exposed to the incident light. Furthermor, blood vessels detour around the fovea. This arrangement significantly reduces scattering of the light rays.

Visual System (I): Overview & Geniculate Part

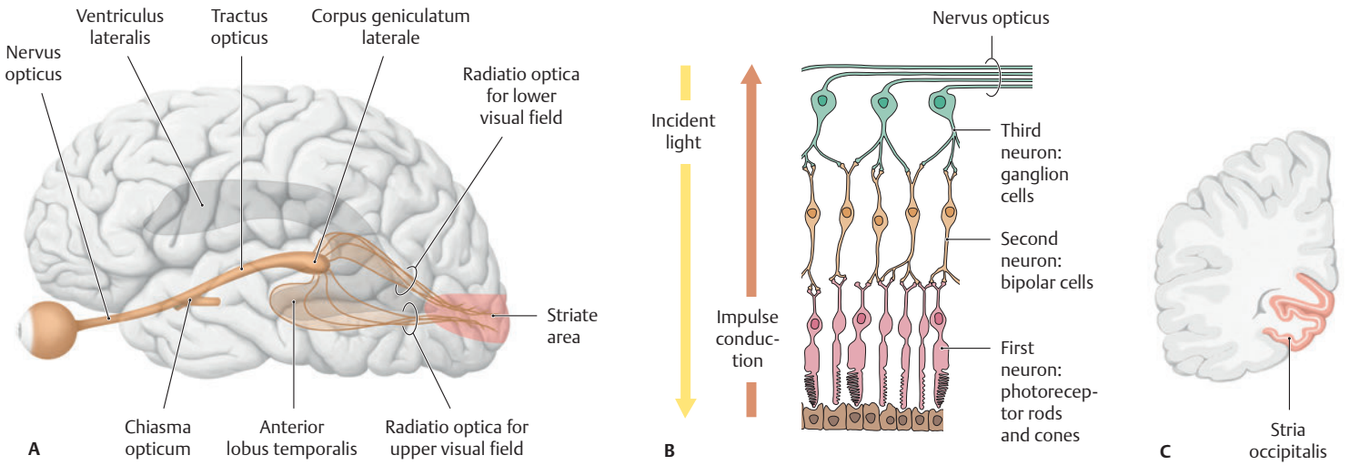


Fig. 9.49 **Overview of the visual pathway**
Left lateral view. The visual pathway extends from the eye, an anterior prolongation of the diencephalon, back to the polus occipitalis. Thus, it encompasses almost the entire longitudinal axis of the brain. The principal stations are as follows:
Retina: The first three neurons of the visual pathway (**B**):

- First neuron: photoreceptor rods and cones, located on the deep retinal surface opposite the direction of the incoming light ("inversion of the retina").
- Second neuron: bipolar cells.
- Third neuron: ganglion cells whose axons are collected to form the nervus opticus.

Nervus opticus (CN II), chiasma opticum, and tractus opticus: This neural portion of the visual pathway is part of the central nervous system and is surrounded by meninges. Thus, the nervus opticus is actually a tract rather than a true nerve. The nervi optici join below the base of the diencephalon to form the chiasma opticum, which then divides into the two tractus optici. Each of these tracts divides in turn into a radix lateralis and radix medialis.

Corpus geniculatum laterale: Ninety percent of the axons of the third neuron (= 90 % of the nervus opticus fibers) terminate in the corpus geniculatum laterale on neurons that project to the striate area (visual cortex, see below). This is the *geniculate part of the visual pathway*. It is concerned with *conscious* visual perception and is conveyed by the radix lateralis of the tractus opticus. The remaining 10% of the third-neuron axons in the visual pathway do not terminate in the corpus geniculatum laterale. This is the *nongeniculate part of the visual pathway* (radix medialis, see **Fig. 9.54**), and its signals are not consciously perceived.
Radiatio optica and visual cortex (striate area): The Radiatio optica begins in the corpus geniculatum laterale, forms a band that winds around the cornua inferius and posterius of the ventriculi laterales, and terminates in the visual cortex or striate area (= Brodmann area 17). Located in the lobus occipitalis, the visual cortex can be grossly identified by a prominent stripe of white matter in the otherwise gray cortex cerebri (the stria occipitalis, see **C**). This white stripe runs parallel to the brain surface and is shown in the inset, where the gray matter of the visual cortex is shaded light red.

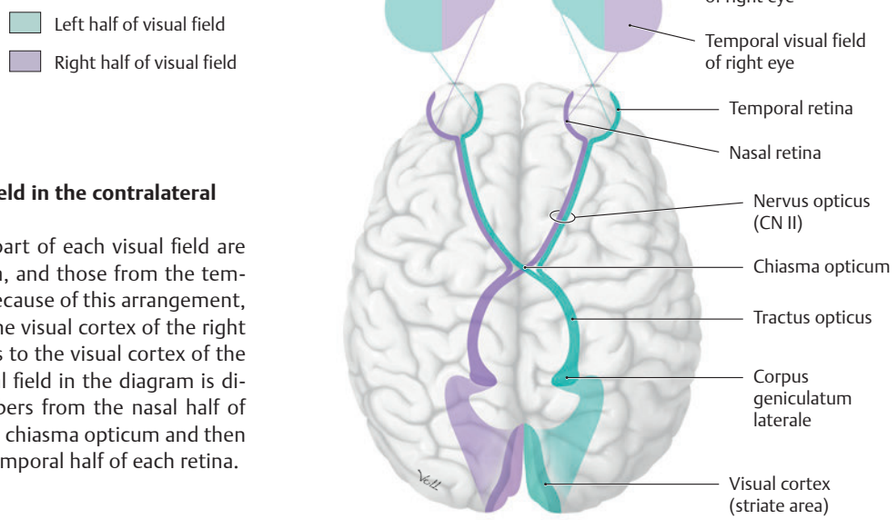


Fig. 9.50 **Representation of each visual field in the contralateral visual cortex**
Superior view. The light rays in the *nasal* part of each visual field are projected to the *temporal* half of the retina, and those from the temporal part are projected to the nasal half. Because of this arrangement, the left half of the visual field projects to the visual cortex of the right polus occipitalis, and the right half projects to the visual cortex of the left polus occipitalis. For clarity, each visual field in the diagram is divided into two halves. *Note:* The axonal fibers from the nasal half of each retina cross to the opposite side at the chiasma opticum and then travel with the uncrossed fibers from the temporal half of each retina.

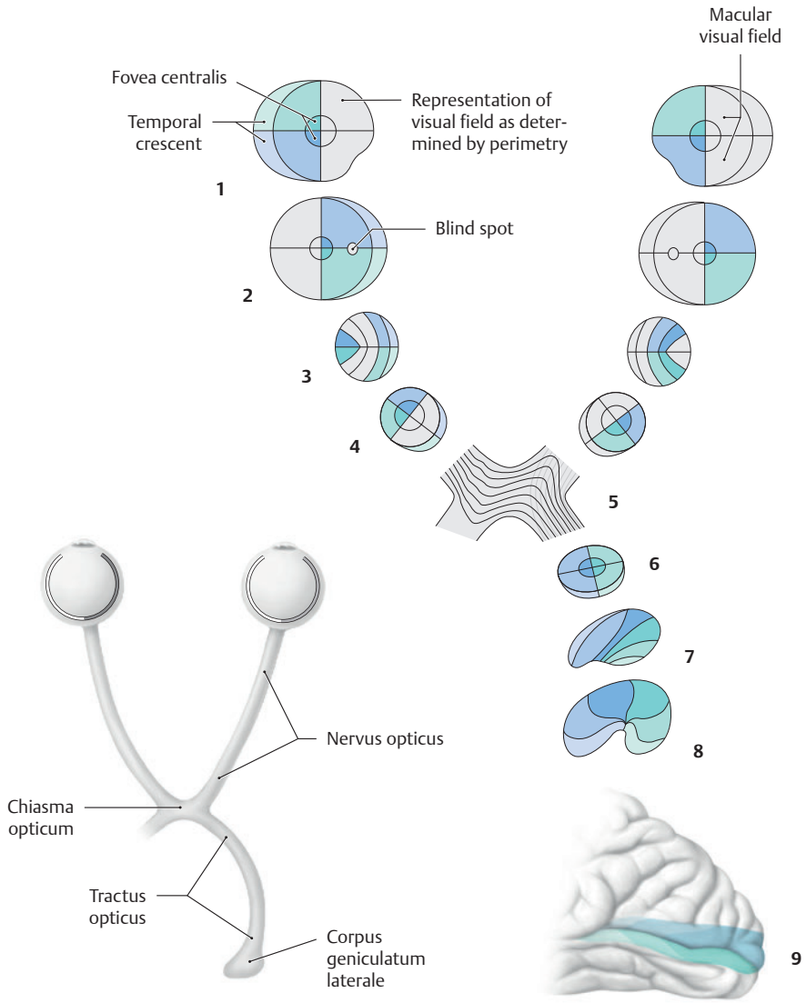


Fig. 9.51 **Geniculate part of visual pathway: topographic organization**

The visual field is divided into four quadrants: upper temporal, upper nasal, lower nasal, and lower temporal. The lower nasal quadrant is indented by the nose. The representation of this subdivision is continued into the visual cortex. *Note:* Only the left visual hemifield (blue) is shown here (compare to **Fig. 9.50**).

1 Visual hemifield: Each visual hemifield is divided into three zones (indicated by color shading):

- Fovea centralis: The smallest and darkest zone is at the center of the visual field. It corresponds to the fovea centralis, the point of maximum visual acuity on the retina. The fovea centralis has a high receptor density; accordingly, a great many axons pass centrally from its receptors. It is therefore represented by a disproportionately large area in the visual cortex.
- Macular visual field: The largest zone in the visual hemisphere; it also contains the blind spot.
- Temporal crescent: The temporal, monocular part of the visual field. This corresponds to more peripheral portions of the retina that contain fewer receptors and therefore fewer axons, resulting in a smaller representational area in the visual cortex.

2 Retinal projection: All light that reaches the retina must pass through the narrow pupilla, which functions like the aperture of a camera. Up/down and nasal/temporal are therefore reversed when the image is projected on the retina.

3,4 Nervus opticus: In the distal part of the nervus opticus, the fibers that represent the macular visual field initially occupy a lateral position (**3**), then move increasingly toward the center of the nerve (**4**).

5 Chiasma opticum: While traversing the chiasma opticum, the fibers of the nasal retina of the nervus opticus cross the midline to the opposite side.

6 Start of the tractus opticus: Fibers from the corresponding halves of the retinas unite (e.g., right halves of the left and right retinas in the right tractus opticus). The impulses from the left visual field (right retinal half) will therefore terminate in the right striate area.

7 End of the tractus opticus: Fibers are collected to form a wedge before entering the corpus geniculatum laterale.

8 Corpus geniculatum laterale: Macular fibers occupy almost half of the wedge. After the fibers are relayed to the fourth neuron, they project to the posterior end of the polus occipitalis (= visual cortex).

9 Visual cortex: There exists a point-to-point (retinotopic) correlation between the number of axons in the retina and the number of axons in the visual cortex (e.g., the central part of the visual field is represented by the largest area in the visual cortex, due to the large number of axons concentrated in the fovea centralis). The central lower half of the visual field is represented by a large area on the polus occipitalis above the sulcus calcarinus; the central upper half of the visual field is represented below the sulcus.

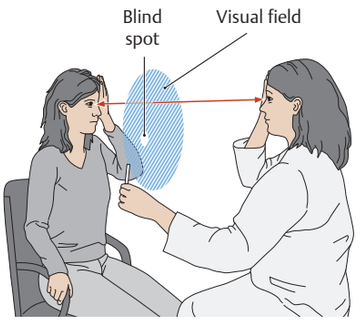


Fig. 9.52 **Informal visual field examination with the confrontation test**

The visual field examination is an essential step in the examination of lesions of the visual pathway (see **Fig. 9.53**). The **confrontation test** is an *informal* test in which the examiner (with an intact visual field) and the patient sit face-to-face, cover one eye, and each fixes their gaze on the other's open eye, creating identical visual axes. The examiner then moves his or her index finger from the outer edge of the visual field toward the center until the patient signals that he or she can see the finger. With this test the examiner can make a gross assessment as to the presence and approximate location of a possible visual field defect. The *precise* location and extent of a visual field defect can be determined by **perimetry**, in which points of light replace the examiner's finger. The results of the test are entered in charts that resemble the small diagrams in **Fig. 9.53**.

Visual System (II): Lesions & Nongeniculate Part

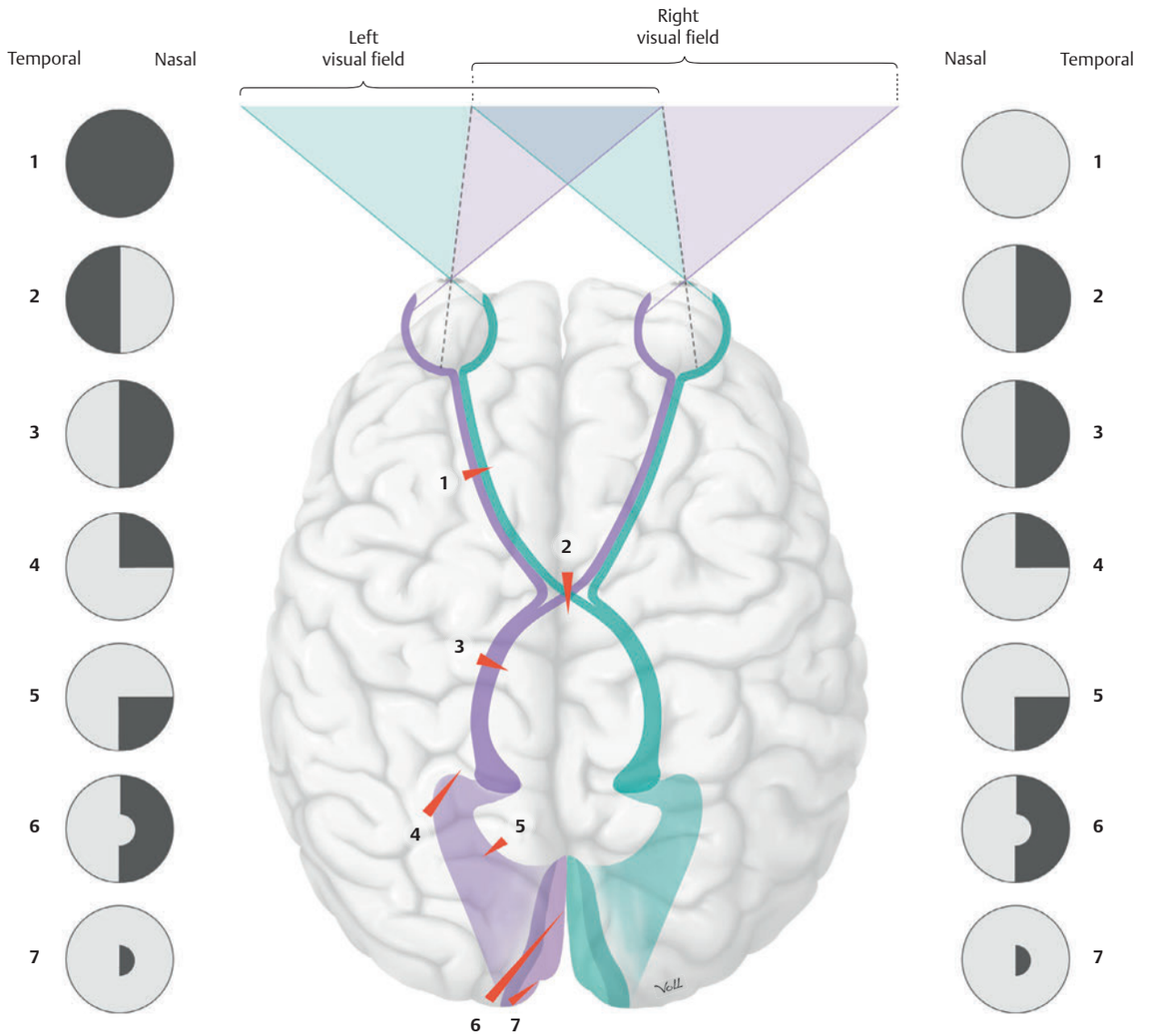


Fig. 9.53 **Visual field defects and lesions of the visual pathway**
Circles represent the perceived visual disturbances (scotomas, or areas of darkness) in the left and right eyes. These characteristic visual field defects (anopias) result from lesions at specific sites along the visual pathway. Lesion sites are illustrated in the left visual pathway as red wedges. The nature of the visual field defect often points to the location of the lesion. *Note:* Lesions past the chiasma opticum will all be homonymous (same visual field in both eyes).

1 Unilateral nervus opticus lesion: Blindness (amaurosis) in the affected eye.
2 Lesion of chiasma opticum: Bitemporal hemianopia (think of a horse wearing blinders). Only fibers from the nasal portions of the retina (representing the temporal visual field) cross in the chiasma opticum.
3 Unilateral tractus opticus lesion: Contralateral homonymous hemianopia. The lesion interrupts fibers from the temporal portion of the retina on the ipsilateral side and nasal portions of the retina on the contralateral side. The patient therefore has visual impairment of the same visual hemisphere in both eyes.
4 Unilateral lesion of the radiatio optica in the anterior lobus temporalis: Contralateral upper quadrantanopia ("pie in the sky" deficit). Lesions in the anterior lobus temporalis affect only those fibers winding under the cornu inferius of the ventriculus lateralis (see **Fig. 9.49**). These fibers represent only the upper half of the visual field (in this case the nasal portion).
5 Unilateral lesion of the radiatio optica in the lobus parietalis: Contralateral lower quadrantanopia. Fibers from the lower half of the visual field course superior to the ventriculus lateralis in the lobus parietalis.
6 Lobus occipitalis lesion: Homonymous hemianopia. The lesion affects the radiationes opticae from both the upper and lower visual fields. However, as the radiatio optica fans out widely before entering the visual cortex, foveal vision is often spared. These lesions are most commonly due to intracerebral hemorrhage; the visual field defects vary considerably with the size of the hemorrhage.
7 Polus occipitalis lesion (confined to cortical area): Homonymous hemianopic central scotoma. The cortical areas of the polus occipitalis represent the macula.

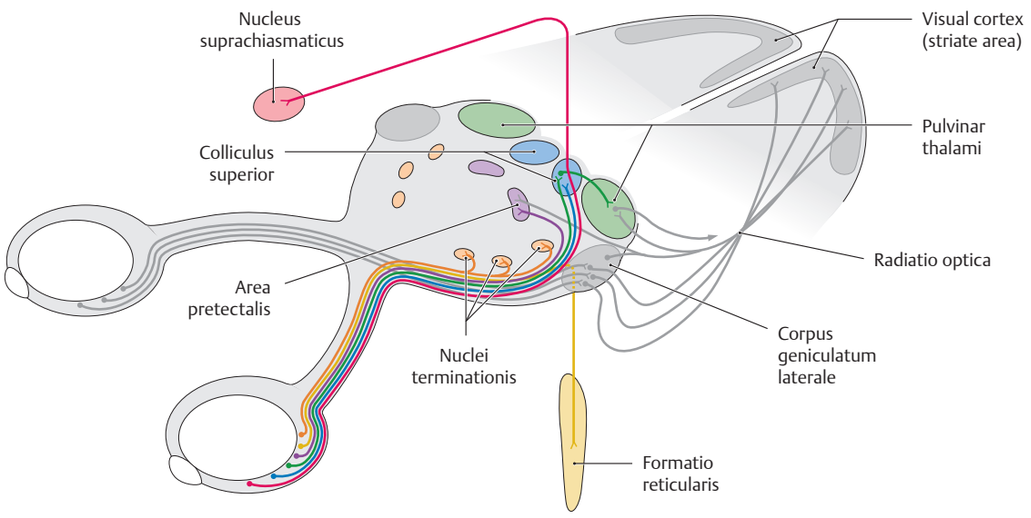


Fig. 9.54 **Nongeniculate part of the visual pathway**
Approximately 10% of the axons of the nervus opticus do not terminate on neurons in the corpus geniculatum laterale for projection to the visual cortex. They continue along the radix medialis of the tractus opticus, forming the *nongeniculate part* of the visual pathway. The information from these fibers is not processed at a conscious level but plays an important role in the unconscious regulation of various vision-related processes and in visually mediated reflexes (e.g., the afferent limb of the pupillary light reflex). Axons from the nongeniculate part of the visual pathway terminate in the following regions:

- Axons to the colliculus superior transmit kinetic information that is necessary for tracking moving objects by unconscious eye and head movements (retinotectal system).
- Axons to the area pretectalis transmit afferents for pupillary responses and accommodation reflexes (retinopretectal system). Subdivision into specific nuclei has not yet been accomplished in humans, and so the term "area" is used.
- Axons to the nucleus suprachiasmaticus of the hypothalamus influence circadian rhythms.
- Axons to the thalamic nuclei (tractus opticus) in the tegmentum mesencephali and to the nuclei vestibulares transmit afferent fibers for optokinetic nystagmus (=jerky, physiological eye movements during the tracking of fast-moving objects). This has also been called the "accessory visual system."
- Axons to the pulvinar thalami form the visual association cortex for oculomotor function (neurons are relayed in the colliculus superior).
- Axons to the nuclei parvocellulares of the formatio reticularis function during arousal.

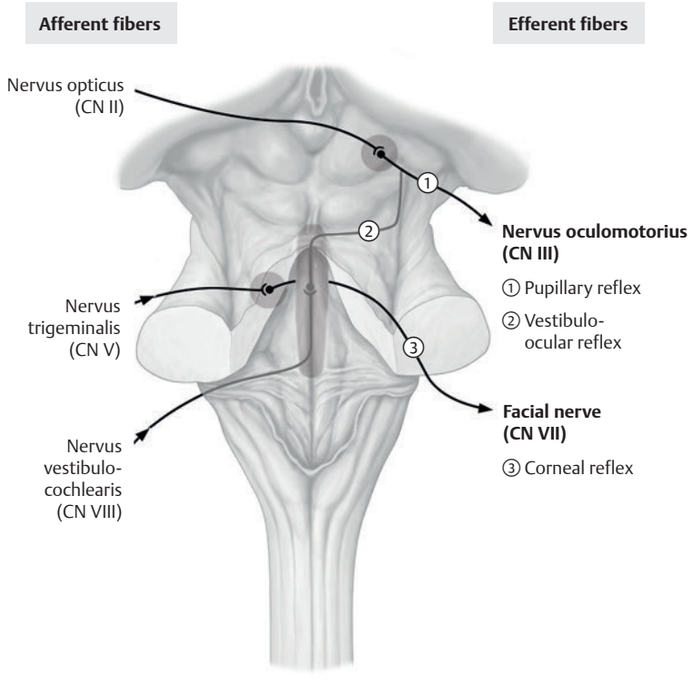


Fig. 9.55 **Truncus encephali reflexes**
Truncus encephali reflexes are important in the examination of comatose patients. Loss of all truncus encephali reflexes is considered evidence of brain death. Three of these reflexes are described below:
Pupillary reflex: The pupillary reflex relies on the nongeniculate parts of the visual pathway (see **Fig. 9.57**). The afferent fibers for this reflex come from the nervus opticus, which is an extension of the diencephalon. The efferents for the pupillary reflex come from the accessory nucleus of the nervus oculomotorius (CN III), which is located in the truncus encephali. Loss of the pupillary reflex may signify a lesion of the diencephalon (interbrain) or mesencephalon (midbrain).
Vestibulo-ocular reflex: Irrigating the porus acusticus externus with cold water in a normal individual evokes nystagmus that beats toward the opposite side (afferent fibers are conveyed in the nervus vestibulocochlearis [CN VIII], efferent fibers in the nervus oculomotorius [CN III]). When the vestibulo-ocular reflex is absent in a comatose patient, it is considered a poor sign because this reflex is the most reliable clinical test of truncus encephali function.
Corneal reflex: This reflex is not mediated by the visual pathway. The afferent fibers for the reflex (elicited by stimulation of the cornea, as by touching it with a sterile cotton wisp) are conveyed in the nervus trigeminus (CN VI) and the efferent fibers (contraction of the orbicularis oculi in response to corneal irritation) in the nervus facialis (CN VII). The relay center for the corneal reflex is located in the pontine region of the truncus encephali. Loss of the corneal reflex can be due to sensory loss in CN V_1, weakness or paralysis of the nervus facialis (CN VII), or to truncus encephali disease.

Visual System (III): Reflexes

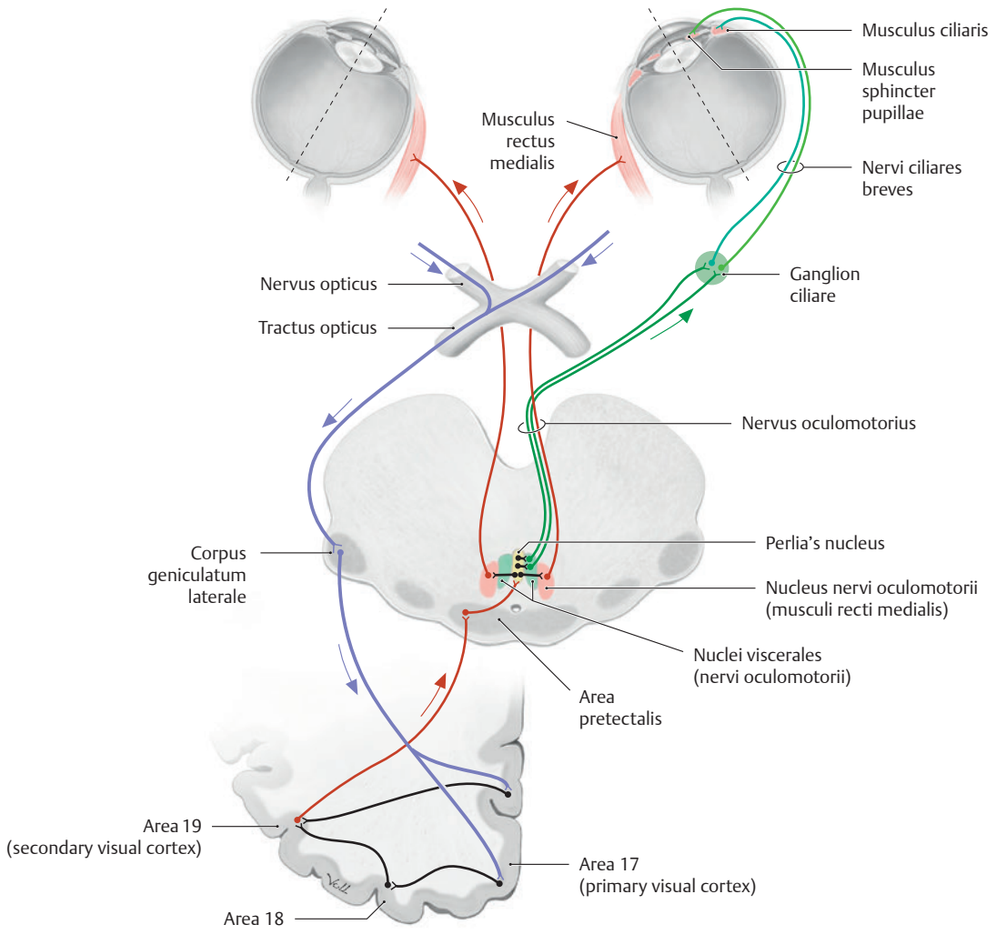


Fig. 9.56 **Pathways for convergence and accommodation**

When the distance between the eyes and an object decreases, three processes must occur in order to produce a sharp, three-dimensional visual impression (the first two are simultaneous):

1. Convergence (red): The visual axes of the eyes move closer together. The two musculi recti mediales contract to move the axis opticus medially. This keeps the image of the approaching object on the fovea centralis.
2. Accommodation: The lenses adjust their focal length. The curvature of the lens is increased to keep the image of the object sharply focused on the retina. The musculus ciliaris contracts, which relaxes the tension on the fibrae zonulares. The intrinsic pressure of the lens then causes it to assume a more rounded shape. (*Note:* The lens is flattened by the contraction of the fibrae zonulares, which are attached to the musculus ciliaris.)
3. Pupillary constriction: The pupil is constricted by the musculus sphincter pupillae to increase visual acuity.

Convergence and accommodation may be conscious (fixing the gaze on a near object) or unconscious (fixing the gaze on an approaching automobile).

Pathways: The pathways can be broken into three components:

1. Geniculate visual pathway (purple): Axons of the first neurons (photoreceptors) and second neurons (bipolar cells) relay sensory information to the third neurons (retinal ganglion cells), which course in the nervus opticus (CN II) to the corpus geniculatum laterale. There they synapse with the fourth neuron, whose axons project to the primary visual cortex (area 17).
2. Visual cortexes to cranial nerve nuclei: Interneurons (black) connect the primary (area 17) and secondary (area 19) visual cortexes. Synaptic relays (red) connect area 19 to the area pretectalis and ultimately Perlia's nucleus (yellow), located between the two nuclei viscerales nervi oculomotorii (green).
3. Nervi craniales: At Perlia's nucleus, the pathway for convergence diverges with the pathways for accommodation and pupillary constriction:
   - Convergence: Neurons relay impulses to the somatomotor nucleus nervi oculomotorii, whose axons pass directly to the musculus rectus medialis via the nervus oculomotorius (CN III).
   - Accommodation and pupillary constriction: Neurons relay impulses to the nucleus visceralis, whose preganglionic parasympathetic axons project to the ganglion ciliare. After synapsing in the ganglion ciliare, the postganglionic axons pass either to the musculus ciliaris (accommodation) or the musculus sphincter pupillae (pupillary constriction) via the nervi ciliares breves.

Note: The musculus sphincter pupillae light response is abolished in tertiary syphilis, while accommodation (musculus ciliaris) and convergence (musculus rectus medialis) are preserved. This phenomenon, called an Argyll Robertson pupil, indicates that the connections to the musculi ciliaris and sphincter pupillae are mediated by different tracts, although the anatomy of these tracts is not yet fully understood.

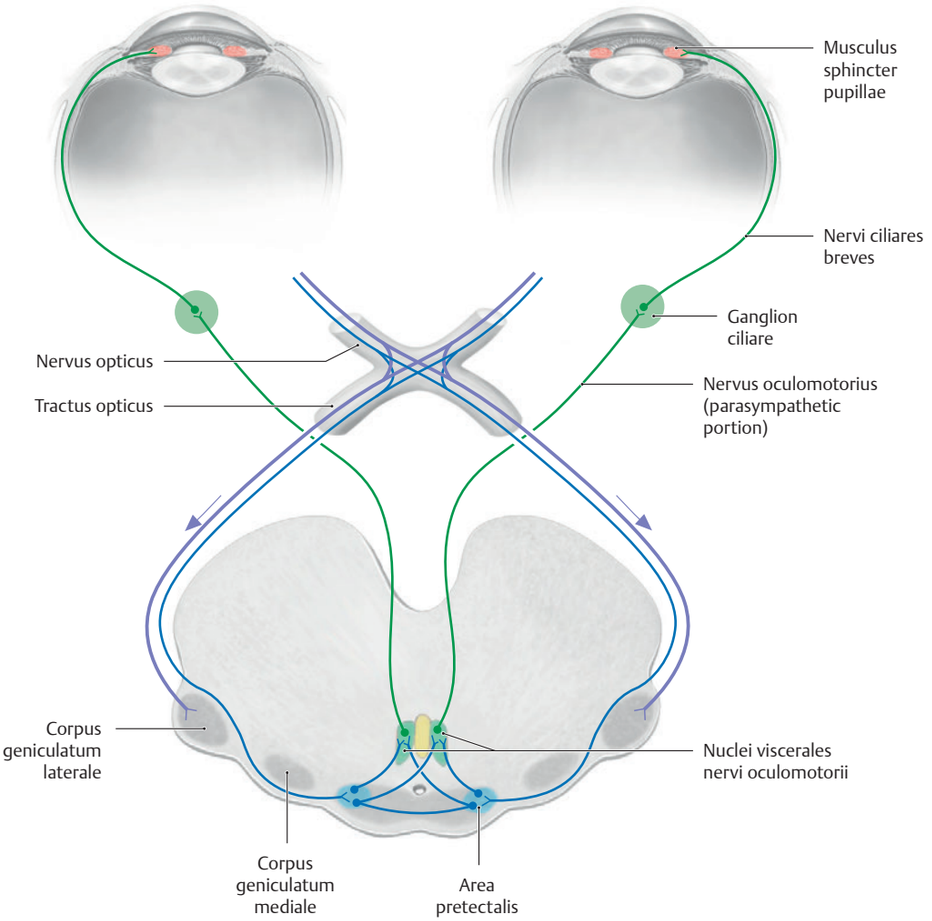


Fig. 9.57 **Pupillary light reflex**

The pupillary light reflex enables the eye to adapt to varying levels of brightness. When a large amount of light enters the eye (e.g., beam of a headlight), the pupilla constricts to protect the photoreceptors in the retina; when the light fades, the pupilla dilates. This reflexive pathway takes place without conscious input via the nongeniculate part of the visual pathway. The reflex can be broken into components:

1. Afferent limb: The first (photoreceptor) and second (bipolar) neurons relay sensory information to the third (retinal ganglion) neurons, which combine to form the nervus opticus (CN II). Most third neurons (purple) synapse at the corpus geniculatum laterale (geniculate part of the visual pathway). The third neurons responsible for the light reflex (blue) synapse at the area pretectalis in the radix media of the tractus opticus (nongeniculate part of the visual pathway). Fourth neurons from the area pretectalis pass to the parasympathetic nuclei viscerales nervi oculomotorii. *Note:* Because both nuclei are innervated, a consensual light response can occur (contraction of one pupilla will cause contraction of the other).
2. Efferent limb: Fifth neurons from the nuclei viscerales nervi oculomotorii (preganglionic parasympathetic neurons) synapse in the ganglion ciliare. Sixth neurons (postganglionic parasympathetic neurons) pass to the musculus sphincter pupillae via the nervi ciliares breves.

Loss of light response: Because fourth neurons from the area pretectalis pass to both nuclei viscerales nervi oculomotorii, a consensual light response can occur (contraction of one pupilla will cause contraction of the other). The light response must therefore be tested both directly and indirectly:

- Direct light response: Tested by covering both eyes of the conscious, cooperative patient and then uncovering one eye. After a short latency period, the pupilla of the light-exposed eye will contract.
- Indirect light response: Tested by placing the examiner's hand on the bridge of the patient's nose, shading one eye from the beam of a flashlight while shining it into the other eye. The object is to test whether shining the light into one eye will cause the pupilla of the shaded eye to contract as well (consensual light response).

Lesions can occur all along the pathway for the pupillary light reflex. The direct and indirect light responses can be used to determine the level:

- Unilateral nervus opticus lesion: This produces blindness on the affected side. If the patient is unconscious or uncooperative, the light responses can determine the lesion, as the afferent limb of the pupillary light reflex is lost. Affected side: No direct light response and no consensual light response on the opposite side. Unaffected side: Direct light response and consensual light response on the opposite (affected) side. Because the efferent limb of the reflex is not mediated by the nervus opticus, the functional afferent limb can bypass the impaired afferent limb.
- Lesion of the parasympathetic nucleus visceralis nervi oculomotorii or the ganglion ciliare: The efferent limb of the pupillary light reflex is lost. Affected side: No direct or indirect pupillary light response on the opposite side. Unaffected side: Direct light response, no indirect light response on the opposite (affected) side.
- Lesion of the radiatio optica or visual cortex (geniculate part of the visual pathway): Intact pupillary reflex (direct and indirect light response on both sides).

Visual System (IV): Coordination of Eye Movement

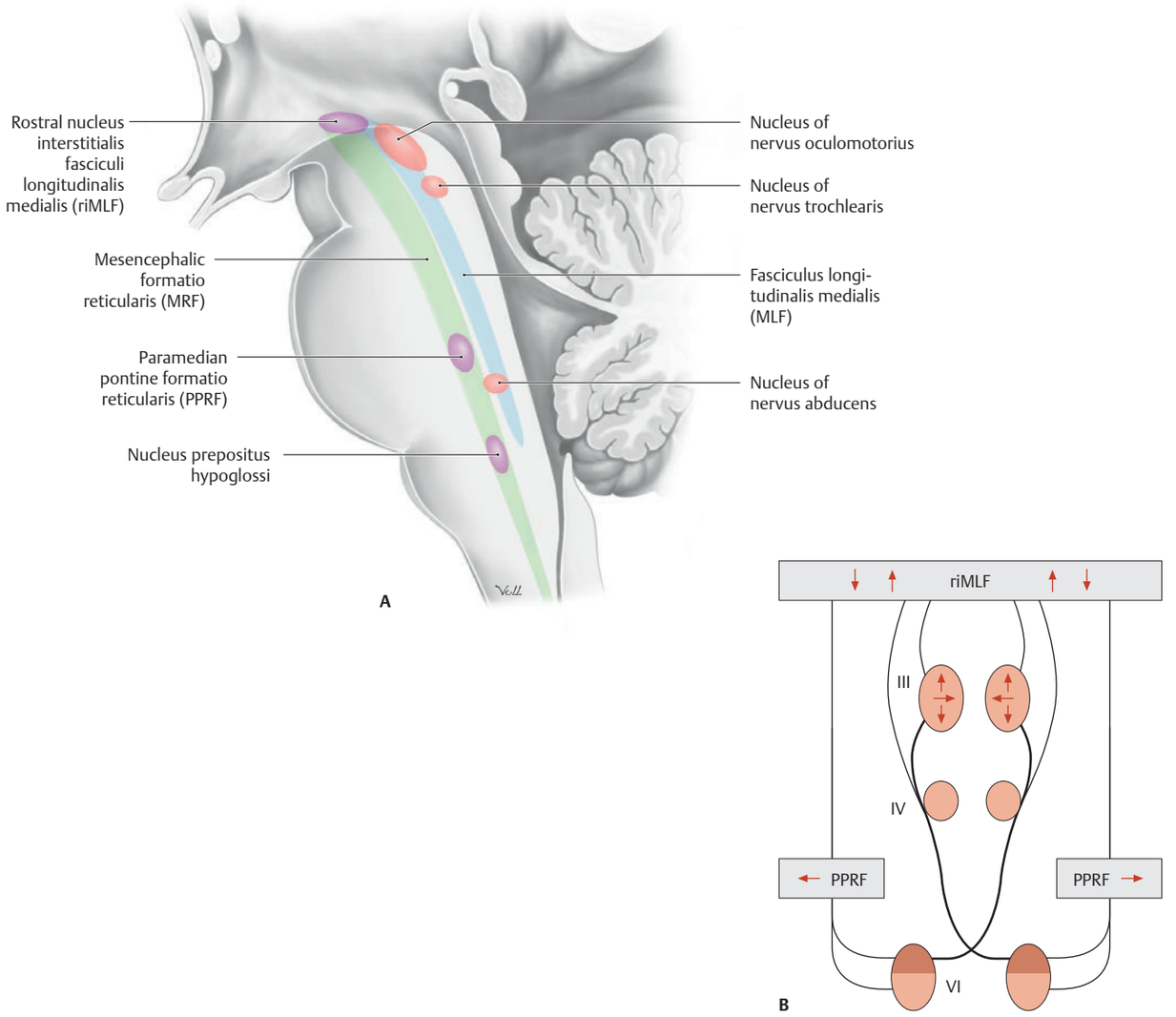


Fig. 9.58 **Oculomotor nuclei and connections in the truncus encephali**

A Midsagittal section viewed from left side. **B** Circuit diagram showing the supranuclear organization of eye movements.

The extraocular muscles receive motor innervation from the nervi oculomotorius (CN III), trochlearis (CN IV), and abducens (CN VI). The concerted movement of the extraocular muscles allows for shifting of gaze, the swift movement of the visual axis toward the intended target. These rapid, precise, "ballistic" eye movements are called *saccades*. They are preprogrammed and, once initiated, cannot be altered until the end of the saccadic movement. The nuclei of CN III, IV, and VI (red) are involved in these saccadic movements. They are interconnected for this purpose by the fasciculus longitudinalis medialis (MLF, blue). Because these complex movements involve all the extraocular muscles and their associated nerves, the activity of the nuclei must be coordinated at a higher, or supranuclear, level. For example, gazing to the right requires four concerted movements:

- Contract right musculus rectus lateralis (CN VI nucleus activated)
- Relax right musculus rectus medialis (CN III nucleus inhibited)
- Relax left musculus rectus lateralis (CN VI nucleus inhibited)
- Contract left musculus rectus medialis (CN III nucleus activated)

These conjugate eye movements are coordinated by premotor nuclei (purple) in the mesencephalic formatio reticularis (green). Horizontal gaze movements are programmed in the nuclear region of the paramedian pontine formatio reticularis (PPRF). Vertical gaze movements are programmed in the rostral nucleus interstitialis fasciculi longitudinalis medialis (riMLF). Both gaze centers establish bilateral connections with the nuclei of CN III, IV, and VI. The tonic signals for maintaining the new eye position originate from the nucleus prepositus hypoglossi.

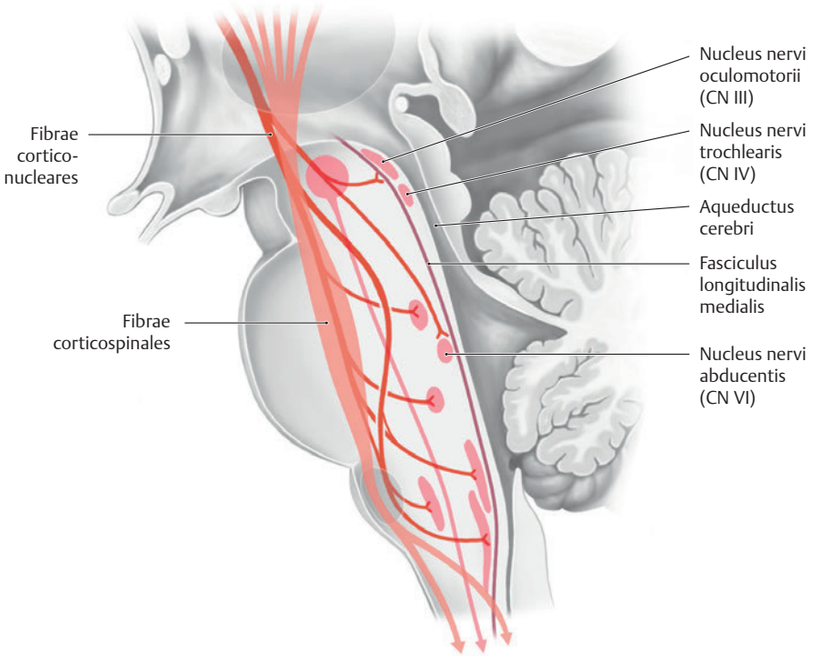


Fig. 9.59 **Course of the fasciculus longitudinalis medialis in the truncus encephali**

Midsagittal section viewed from the left side. The fasciculus longitudinalis medialis (MLF) runs anterior to the aqueductus cerebri on both sides and continues from the mesencephalon to the cervical medulla spinalis. It transmits fibers for the coordination of conjugate eye movements. A lesion of the MLF results in internuclear ophthalmoplegia (see **Fig. 9.60**).

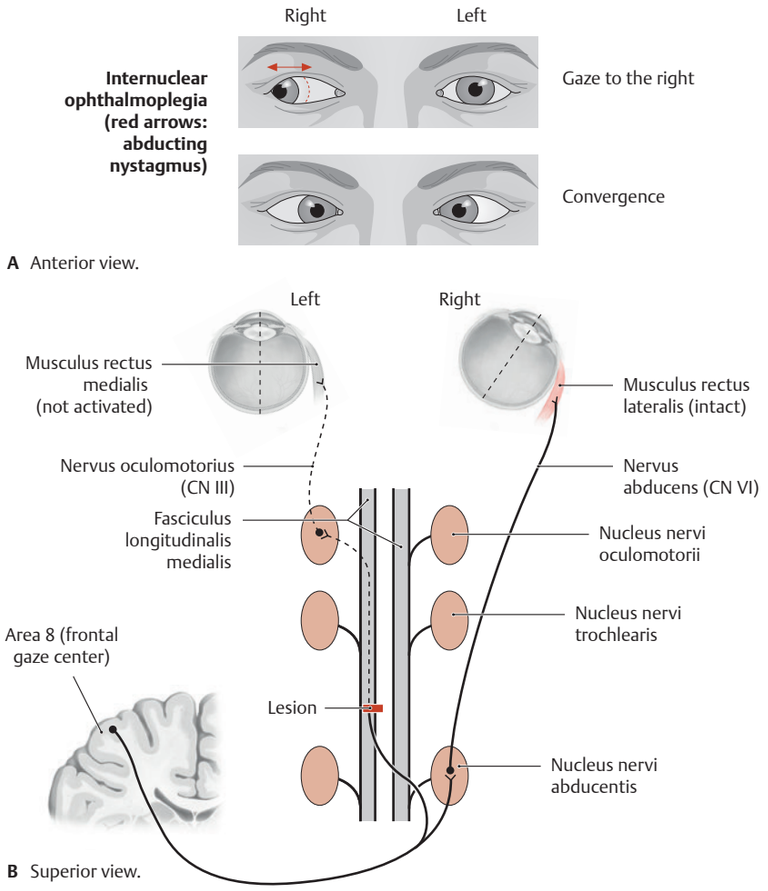


Fig. 9.60 **Internuclear ophthalmoplegia**

The fasciculus longitudinalis medialis (MLF) interconnects the oculomotor nuclei and also connects them with the opposite side. When this "information highway" is interrupted, internuclear ophthalmoplegia develops. This type of lesion most commonly occurs between the nuclei nervi abducentis and oculomotorii. It may be unilateral or bilateral. Typical causes are multiple sclerosis and diminished blood flow. The lesion is manifested by the loss of conjugate eye movements. With a lesion of the left MLF, as shown here, the left musculus rectus medialis is no longer activated during gaze to the right. The eye cannot be moved *inward* on the side of the lesion (loss of the musculus rectus medialis), and the opposite eye goes into an abducting nystagmus (musculus rectus lateralis is intact and innervated by the nervus abducens). Reflex movements such as convergence are not impaired, as there is no peripheral or nuclear lesion, and this reaction is not mediated by the MLF.

Overview & Auris Externa (I)

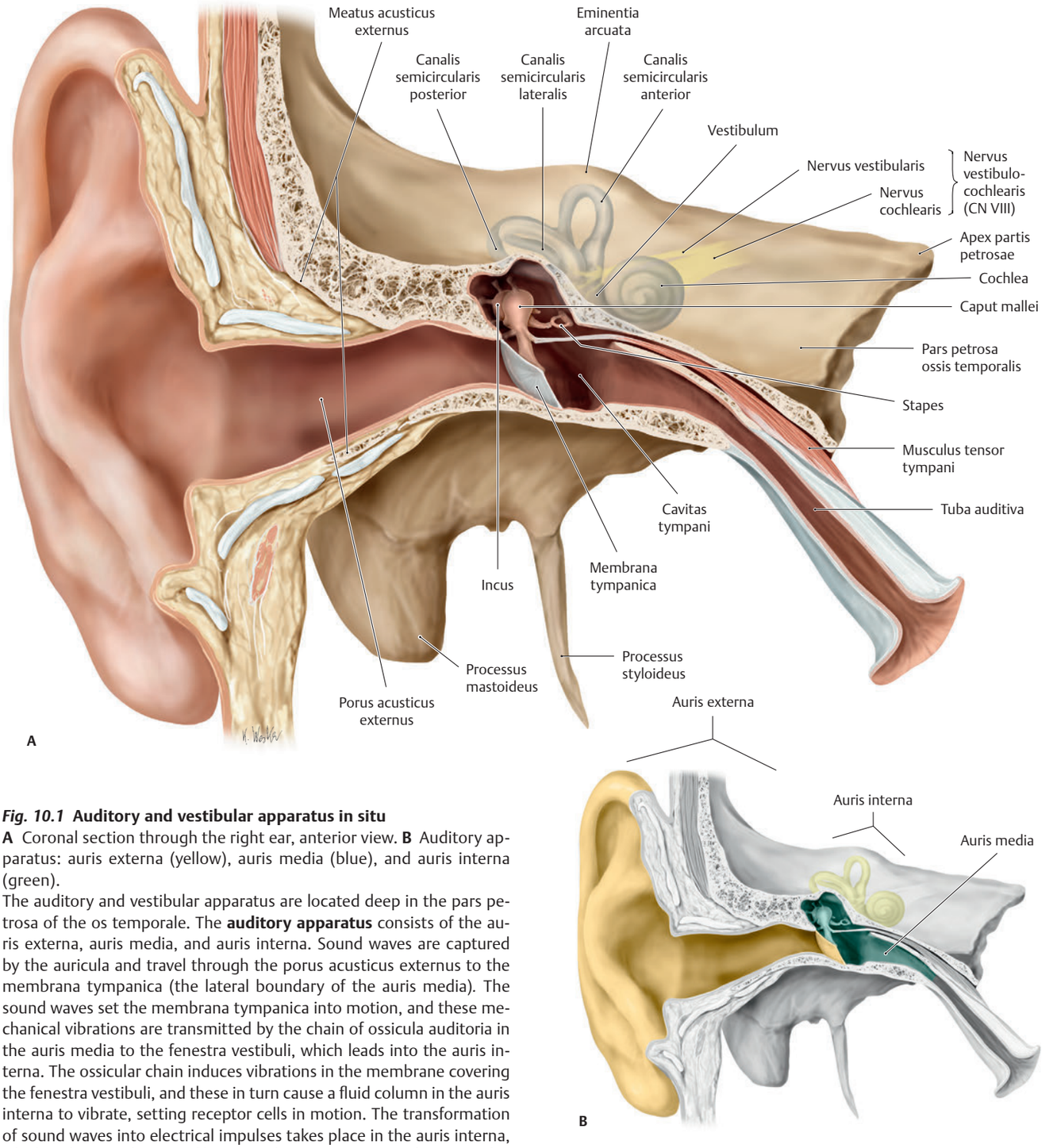


Fig. 10.1 **Auditory and vestibular apparatus in situ**
A Coronal section through the right ear, anterior view. **B** Auditory apparatus: auris externa (yellow), auris media (blue), and auris interna (green).

The auditory and vestibular apparatus are located deep in the pars petrosa of the os temporale. The **auditory apparatus** consists of the auris externa, auris media, and auris interna. Sound waves are captured by the auricula and travel through the porus acusticus externus to the membrana tympanica (the lateral boundary of the auris media). The sound waves set the membrana tympanica into motion, and these mechanical vibrations are transmitted by the chain of ossicula auditoria in the auris media to the fenestra vestibuli, which leads into the auris interna. The ossicular chain induces vibrations in the membrane covering the fenestra vestibuli, and these in turn cause a fluid column in the auris interna to vibrate, setting receptor cells in motion. The transformation of sound waves into electrical impulses takes place in the auris interna, which is the actual organ of hearing. The auris externa and auris media, on the other hand, constitute the *sound conduction apparatus*. The organ of balance is the **vestibular apparatus**, which is also located in the auris interna. It contains the *canales semicirculares* for the perception of angular acceleration (rotational head movements) and the *sacculus* and *utriculus* for the perception of linear acceleration. Diseases of the vestibular apparatus produce dizziness (vertigo).

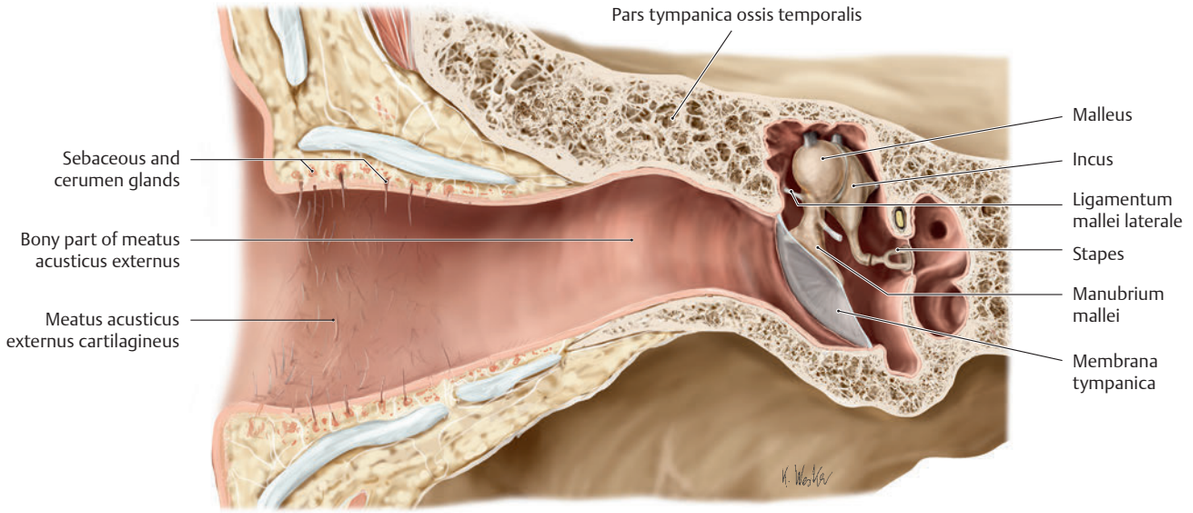


Fig. 10.2 **Meatus acusticus externus, membrana tympanica, and cavitas tympani**
Coronal section, right ear, anterior view. The membrana tympanica (eardrum) separates the meatus acusticus externa from the cavitas tympani of the auris media. The meatus acusticus externus is an S-shaped tunnel that is approximately 3 cm long with an average diameter of 0.6 cm. The outer third of the ear canal is cartilaginous. The inner two thirds of the canal are osseous, the wall being formed by the pars tympanica of the os temporale. The meatus acusticus externus cartilagineus in particular bears numerous sebaceous and cerumen glands beneath the keratinized stratified squamous epithelium. The cerumen glands produce a watery secretion that combines with the sebum and sloughed epithelial cells to form a protective barrier (cerumen, "earwax") that screens out foreign bodies and keeps the epithelium from drying out. If the cerumen absorbs water (e.g., after swimming), it may obstruct the meatus acusticus externus (cerumen impaction), temporarily causing a partial loss of hearing.

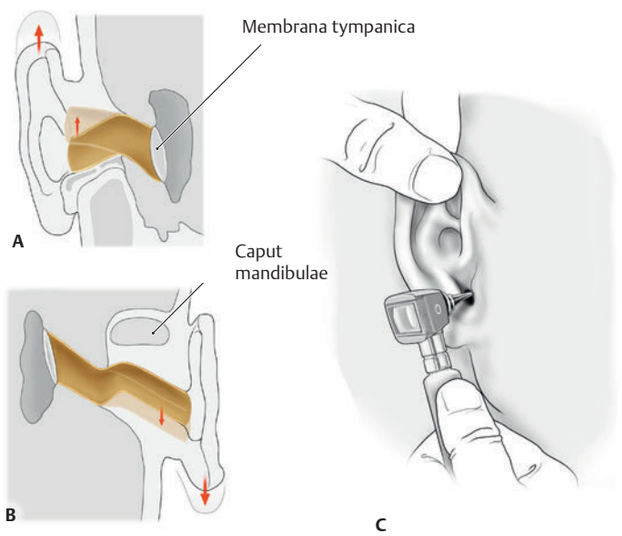


Fig. 10.3 **Curvature of the meatus acusticus externus**
Right ear, anterior view (**A**) and transverse section (**B**).
The meatus acusticus externa is most curved in its cartilaginous portion. When the membrana tympanica is inspected with an otoscope, the auricula should be pulled backward and upward in order to straighten the meatus acusticus externus cartilagineus so that the speculum of the otoscope can be introduced (**C**).
Note the proximity of the cartilaginous anterior wall of the meatus acusticus externus to the articulatio temporomandibularis (TM). This allows the examiner to palpate movements of the caput mandibulae within the TMJ by inserting the small finger into the outer part of the meatus acusticus externus.

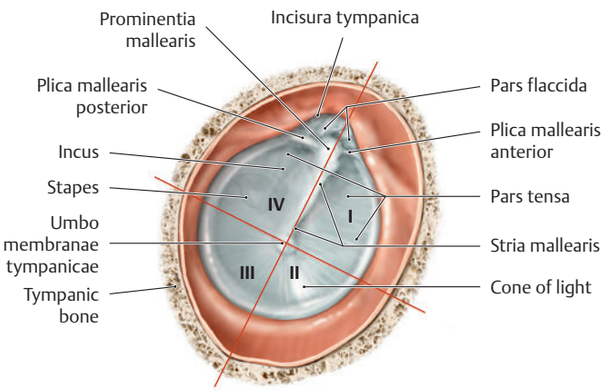


Fig. 10.4 **Membrana tympanica**
Right membrana tympanica, lateral view. The healthy membrana tympanica has a pearly gray color and an oval shape with an average surface area of approximately 75 mm^2. It consists of a lax portion, the *pars flaccida* (Shrapnell membrane), and a larger taut portion, the *pars tensa,* which is drawn inward at its center to form the umbo ("navel"). The umbo membranae tympanicae marks the lower tip of the manubrium mallei, which is attached to the membrana tympanica all along its length. It is visible through the pars tensa as a light-colored streak (stria mallearis). The membrana tympanica is divided into four quadrants in a clockwise direction: anterosuperior (I), anteroinferior (II), posteroinferior (III), posterosuperior (IV). The boundary lines of the quadrants are the stria mallearis and a line intersecting it perpendicularly at the umbo membranae tympanicae. The quadrants of the membrana tympanica are clinically important because they are used in describing the location of lesions. A triangular area of reflected light can be seen in the anteroinferior quadrant of a normal membrana tympanica. The location of this "cone of light" is helpful in evaluating the tension of the membrana tympanica.

Auris Externa (II): Auricula

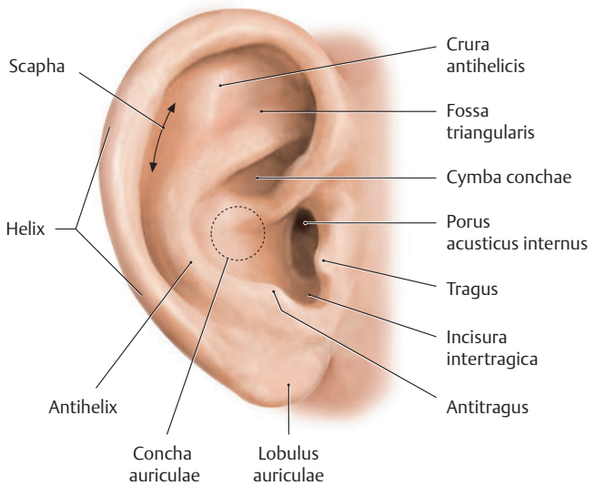


Fig. 10.5 **Right auricula**
The auricula of the ear encloses a cartilaginous framework (cartilago auriculae) that forms a funnel-shaped receptor for acoustic vibrations.

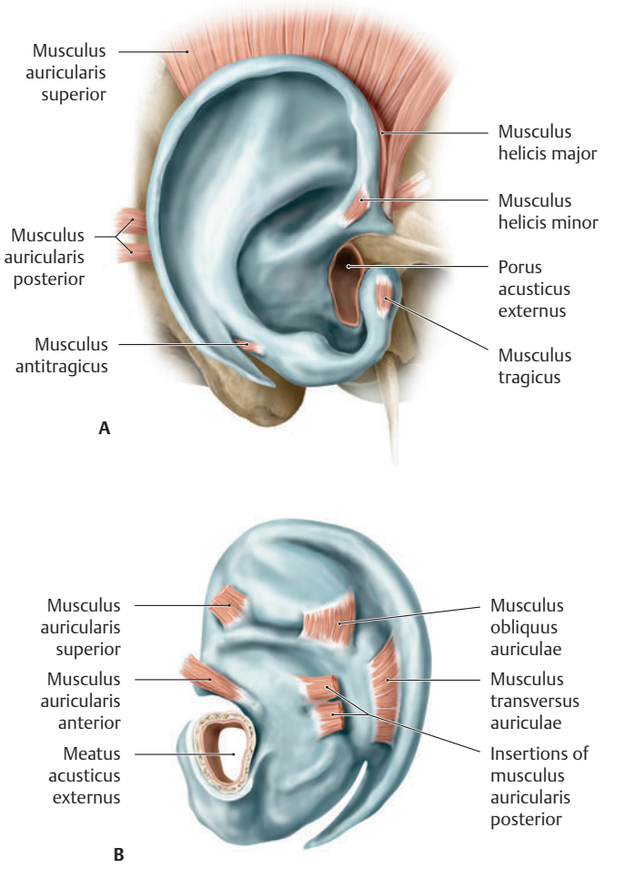
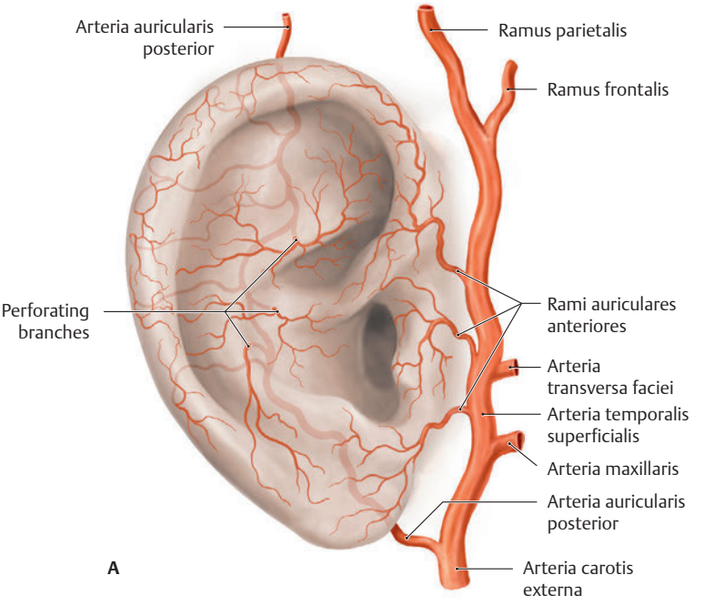


Fig. 10.6 **Cartilage and muscles of the auricula**
A Lateral view of the external surface. **B** Medial view of the posterior surface of the right ear.
The skin (removed here) is closely applied to the elastic cartilage of the auricula (light blue). The muscles of the ear are classified as musculi faciei and, like the other members of this group, are supplied by the nervus facialis (CN VII). Prominent in other mammals, the musculi auriculares are vestigial in humans, with no significant function.



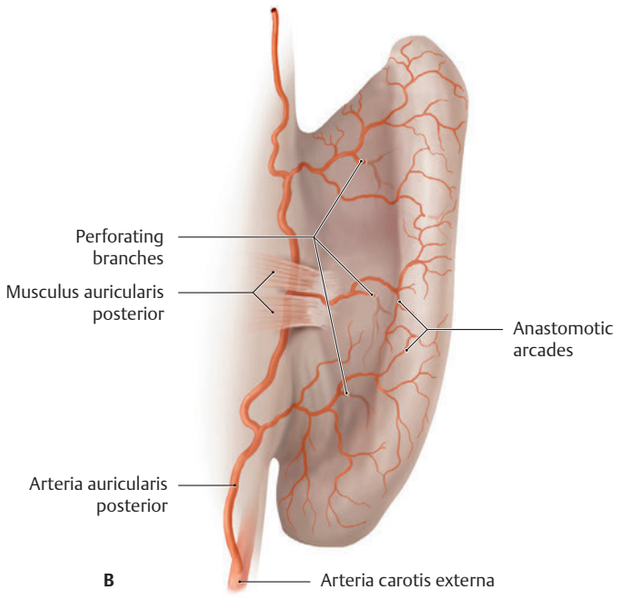


Fig. 10.7 **Arterial supply of the auricula**
Lateral view (**A**) and posterior view (**B**) of right auricula.
The proximal and medial portions of the laterally directed anterior surface of the ear are supplied by the rami auriculares anteriores, which arise from the arteria temporalis superficialis. The other parts of the auricula are supplied by branches of the arteria auricularis posterior, which arises from the arteria carotis externa. These vessels are linked by extensive anastomoses, so operations on the external ear are unlikely to compromise the auricular blood supply. The copious blood flow through the auricula contributes to temperature regulation: dilation of the vessels helps dissipate heat through the skin. The lack of insulating fat predisposes the ear to frostbite, which is particularly common in the upper third of the auricula. The auricular arteries have corresponding veins that drain to the vena temporalis superficialis.

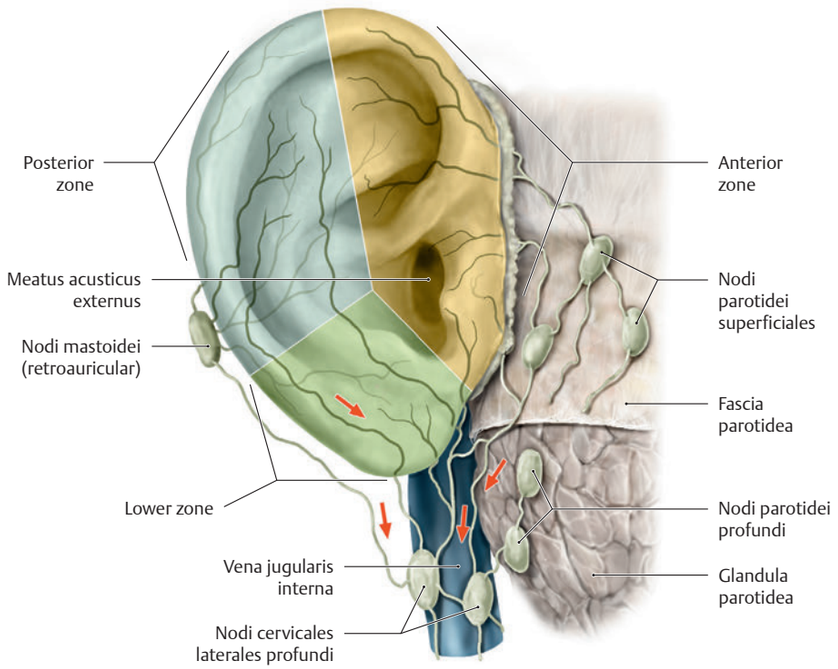


Fig. 10.8 **Auricula and emeatus acusticus externus: lymphatic drainage**
Right ear, oblique lateral view. The lymphatic drainage of the ear is divided into three zones, all of which drain directly or indirectly into the nodi cervicales laterales profundi along the vena jugularis interna. The lower zone drains directly into the nodi cervicales laterales profundi. The anterior zone first drains into the nodi parotidei, the posterior zone into the nodi mastoidei.

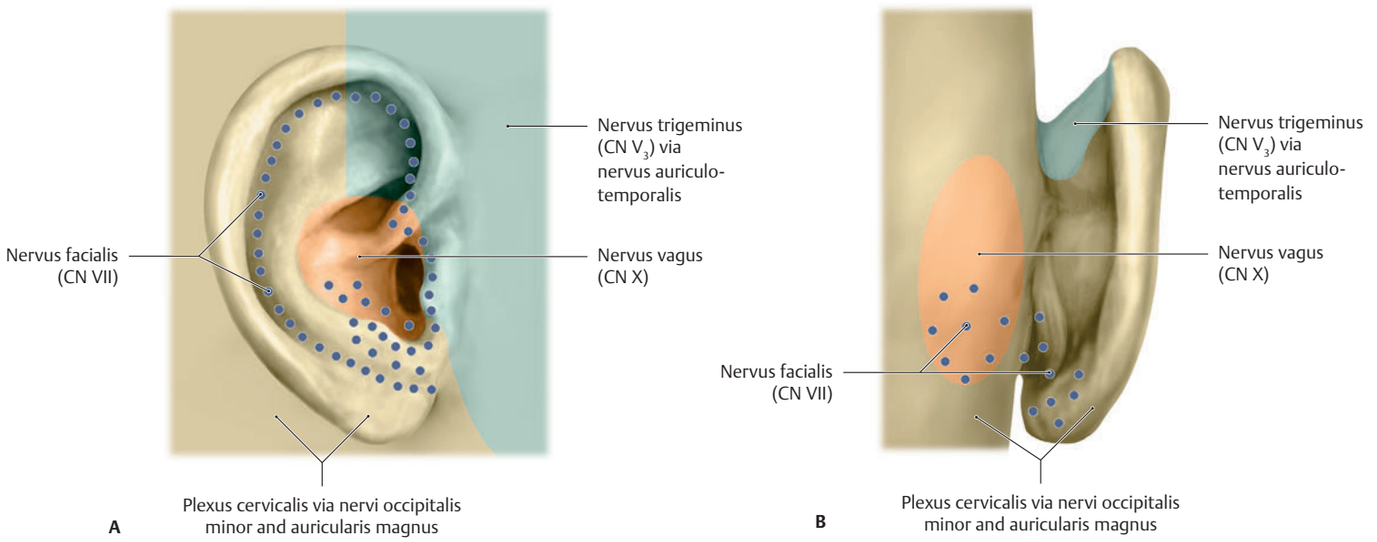


Fig. 10.9 **Sensory innervation of the auricula**
Right ear, lateral view (**A**) and posterior view (**B**). The auricular region has a complex nerve supply because, developmentally, it is located at the boundary between the nervi craniales (pharyngeal arch nerves) and branches of the plexus cervicalis. Three cranial nerves contribute to the innervation of the auricula:

- Nervus trigeminus (CN V_3)
- Nervus facialis (CN VII; the skin area that receives sensory innervation from the nervus facialis is not precisely known)
- Nervus vagus (CN X)

Two branches of the **plexus cervicalis** are involved:

- Nervus occipitalis minor (C2)
- Nervus auricularis magnus (C2, C3)

Note: Because the nervus vagus contributes to the innervation of the meatus acusticus externus (ramus auricularis), mechanical cleaning of the ear canal (by inserting an aural speculum or by irrigating the ear) may evoke coughing and nausea. The ramus auricularis of the nervus vagus passes through the canaliculus mastoideus and through a space between the processus mastoideus and the pars tympanica of the os temporale (fissura tympanomastoidea, see p. 33) to the auris externa and meatus acusticus externus.

Auris Media (I): Cavitas Tympani & Tuba Auditiva

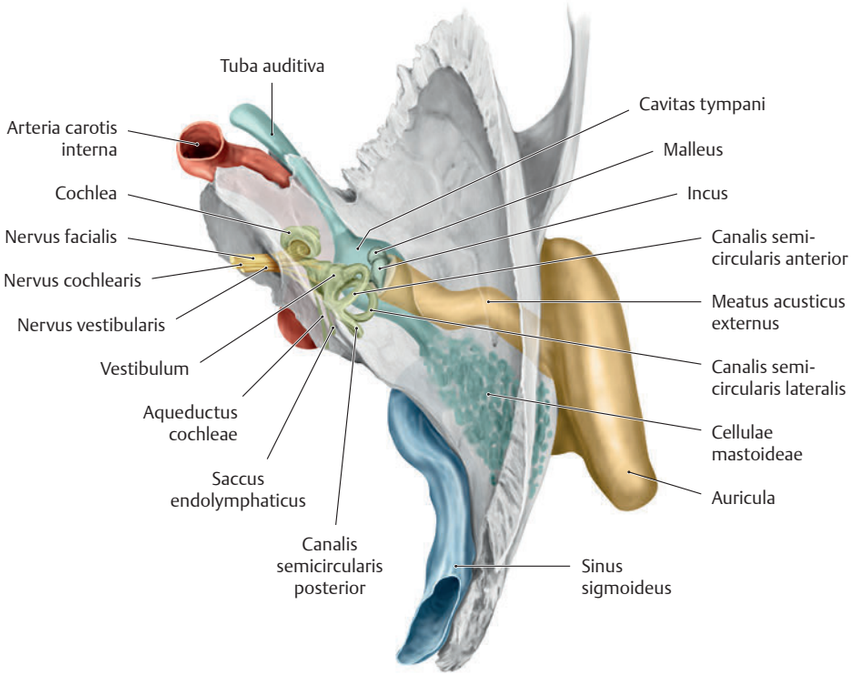


***Fig. 10.10* Auris media and associated structures**
Right pars petrosa ossis temporalis, superior view. The auris media (light blue) is located within the pars petrosa of the os temporale between the auris externa (yellow) and auris interna (green). The cavitas tympani of the auris media contains the chain of ossicula auditoria, of which the malleus (hammer) and incus (anvil) are visible here. The cavitas tympani communicates anteriorly with the pars nasalis pharyngis via the tuba auditiva and posteriorly with the cellulae mastoideae. Infections can spread from the pars nasalis pharyngis to the cellulae mastoideae by this route.

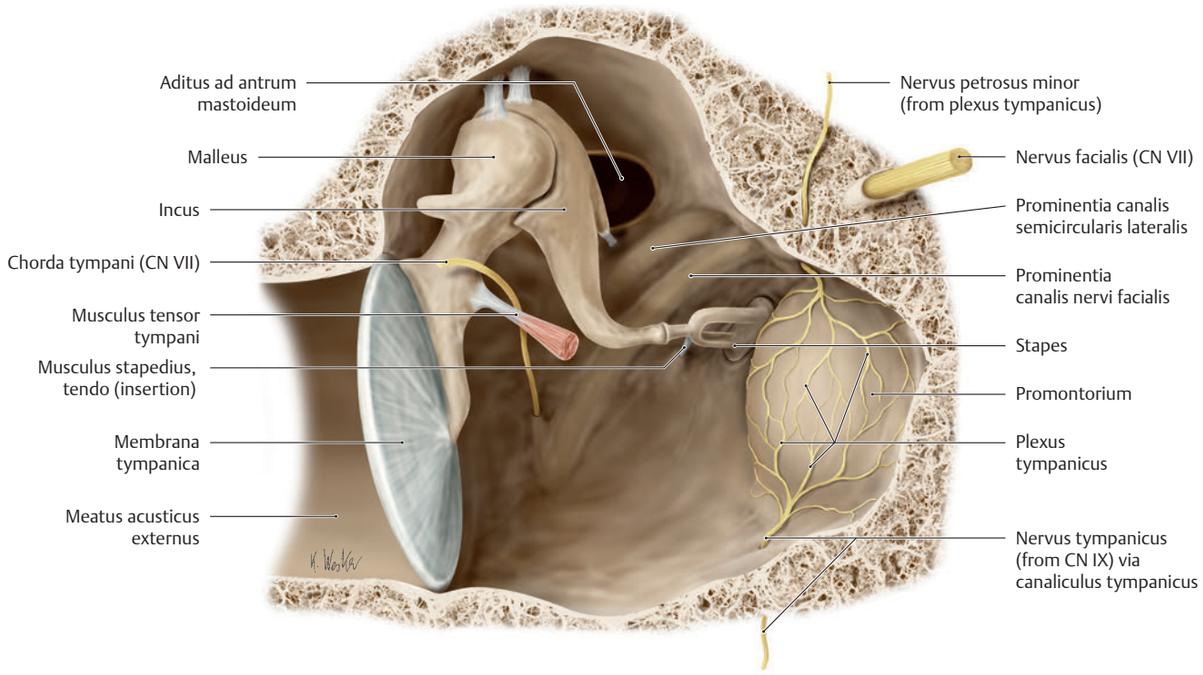


***Fig. 10.11* Walls of the cavitas tympani**
Coronal section anterior view with the anterior wall removed. The cavitas tympani is a slightly oblique space that is bounded by six walls:

- Paries membranaceus (lateral wall): boundary with the auris externa; formed largely by the membrana tympanica.
- Paries labyrinthicus (medial wall): boundary with the auris interna; formed largely by the promontorium, or the bony eminence, overlying the basal turn of the cochlea.
- Paries jugularis (inferior wall): forms the floor of the cavitas tympani and borders on the bulbus superior of the vena jugularis.
- Paries mastoideus (posterior wall): borders on the cellulae of the processus mastoideus, communicating with the cellulae through the aditus (inlet) of the antrum mastoideum.
- Paries tegmentalis (superior wall): forms the roof of the cavitas tympani.
- Paries caroticus (anterior wall) (removed here): includes the opening to the tuba auditiva and borders on the canalis caroticus.

The lateral side of the membrana tympanica is innervated by three nervi craniales: CN V_3 (nervus auriculotemporalis), CN VII (nervus auricularis posterior; pathway uncertain), and CN X (ramus auricularis). The medial side of the membrana tympanica is innervated by CN IX (nervus tympanicus).

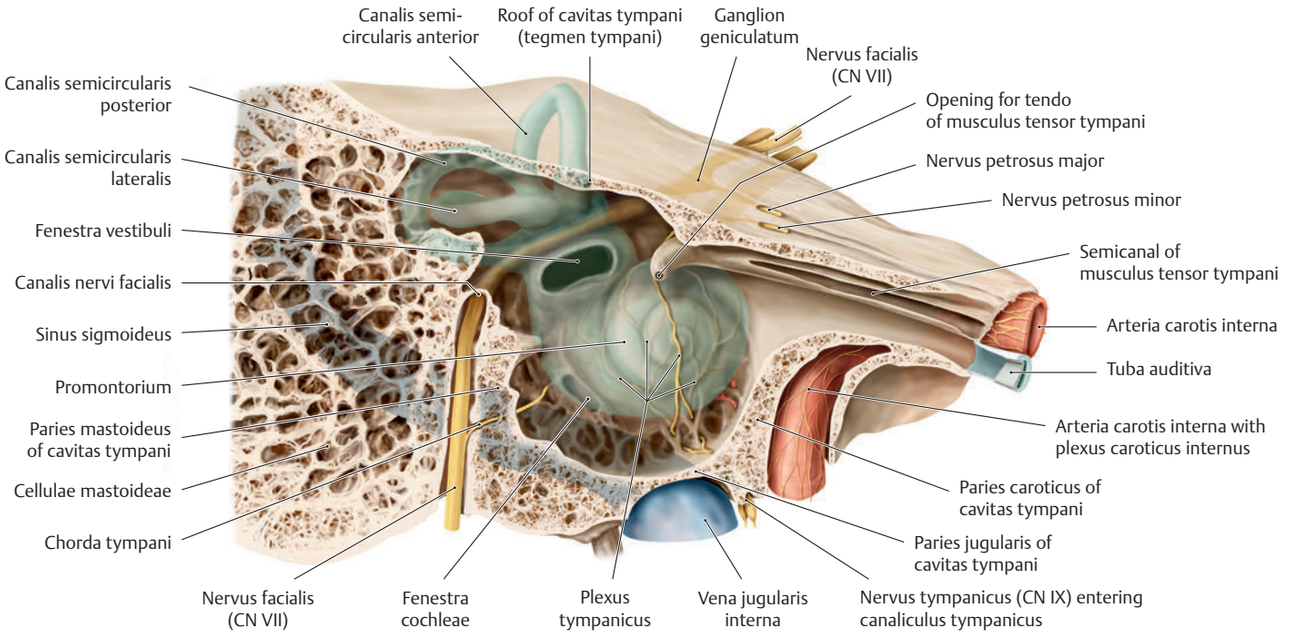


Fig. 10.12 **Nerves in the pars petrosa ossis temporalis**
Oblique sagittal section showing the paries labyrinthicus of the cavitas tympani (see **Fig. 10.11**). The nervus tympanicus branches from CN IX as it passes through the foramen jugulare, and conveys sensory and preganglionic parasympathetic fibers into the cavitas tympani by passing through the canaliculus tympanicus. The fibers from the plexus tympanicus provide sensory innervation to the cavitas tympani (including the medial surface of the membrana tympanica), cellulae mastoideae, and part of the tuba auditiva. *Note:* The lateral surface of the membrana tympanica receives sensory innervation from branches of CN V_3, CN VII, and CN X (see **Fig. 10.11**).

The preganglionic parasympathetic fibers of the nervus tympanicus are reformed from the plexus tympanicus as the nervus petrosus minor. These fibers synapse in the ganglion oticum; the postganglionic parasympathetic fibers travel with the nervus auriculotemporalis (a branch of CN V_3) to supply the glandula parotidea.

In the canalis nervi facialis, the nervus facialis (CN VII) gives off a number of branches: the nervus petrosus major, the nervus stapedius, the chorda tympani, and a ramus auricularis. The nervus petrosus major and the chorda tympani both carry taste fibers and preganglionic parasympathetic fibers. The nervus petrosus major joins with the nervus petrosus profundus (postganglionic sympathetic) to form the nervus canalis pterygoidei (vidian nerve). The preganglionic parasympathetic fibers in the nervus canalis pterygoidei synapse at the ganglion pterygopalatinum. The postganglionic parasympathetic fibers are then distributed by branches of the nervus maxillaris to the glandula lacrimalis, glandulae palatinae, superior glandulae labiales, and mucosa of the sinus paranasales and cavitas nasi. The preganglionic parasympathetic fibers of the chorda tympani synapse at the ganglion submandibulare, and the postganglionic fibers are distributed to the glandulae submandibularis and sublingualis.

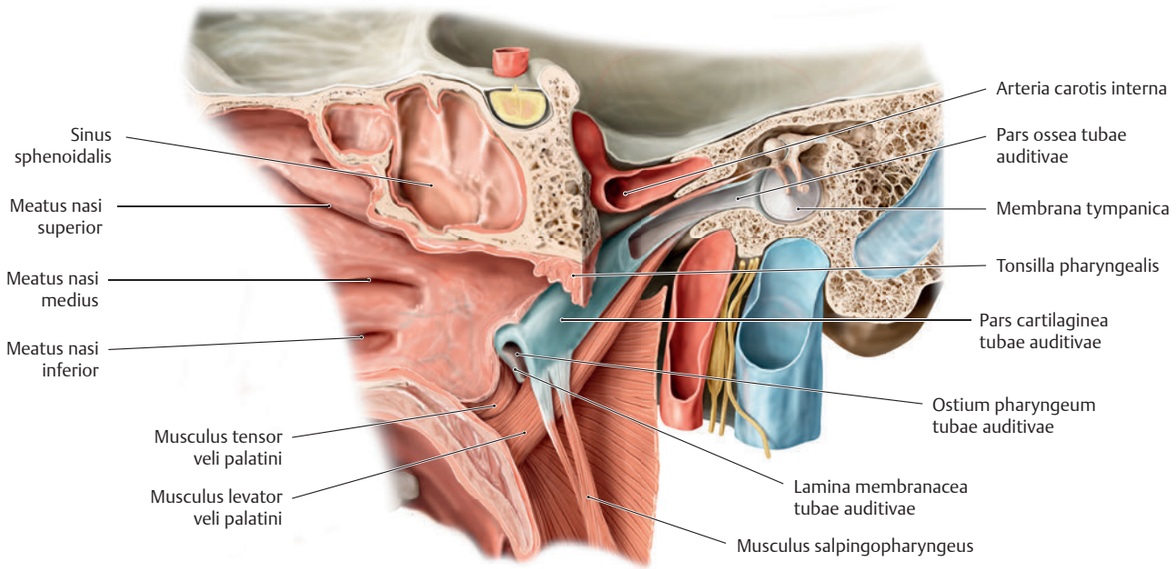


Fig. 10.13 **Tuba auditiva**
Medial view of right cavitas nasi. The tuba auditiva creates an open channel between the auris media and pars nasalis pharyngis. Air passing through the tuba serves to equalize the air pressure on the two sides of the membrana tympanica. This equalization is essential for maintaining normal membrana tympanica mobility, necessary for normal hearing. One third of the tube is bony (in the pars petrosa ossis temporalis). The cartilaginous two thirds continue toward the pars nasalis pharyngis, expanding to form a hook (hamulus) that is attached to a lamina membranacea. The fibers of the musculus tensor veli palatini arise from this lamina; when they tense the palatum molle (during swallowing), these fibers open the tuba auditiva. The tuba is also opened by the musculi salpingopharyngeus and levator veli palatini. The tuba is lined with ciliated respiratory epithelium: the cilia beat toward the pharynx, inhibiting the passage of microorganisms into the auris media.

Auris Media (II): Ossicula Auditoria & Cavitas Tympani

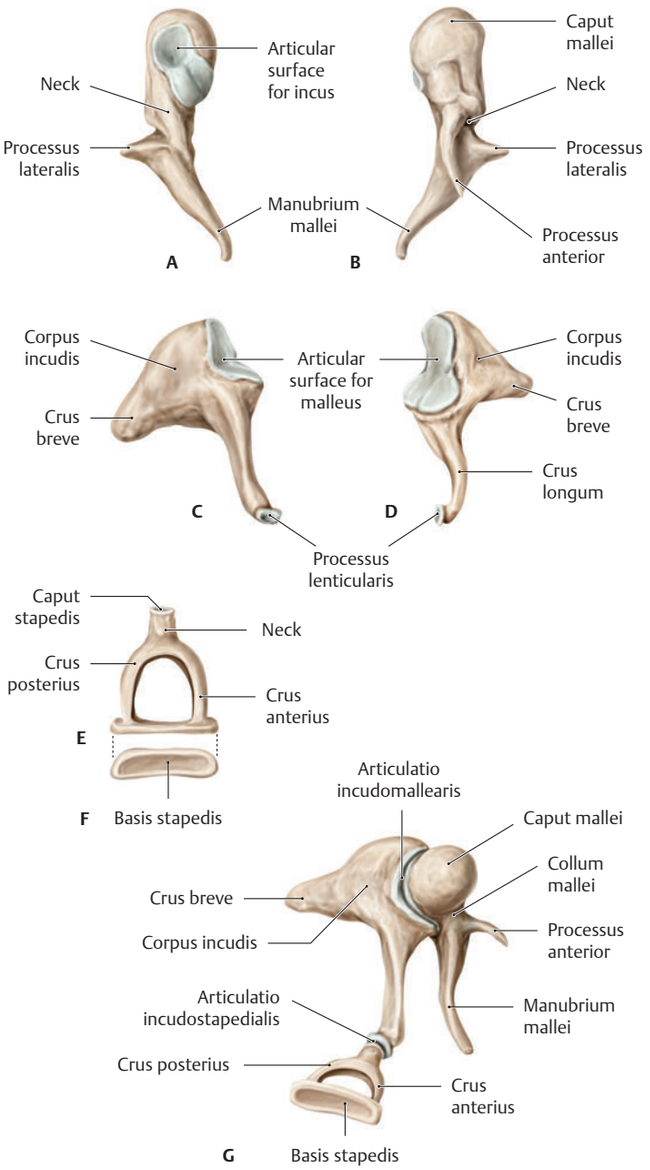


Fig. 10.14 **Ossicula auditoria**
Ossicula auditoria of the left ear. The ossicular chain (**G**) of the auris media establishes an articular connection between the membrana tympanica and the fenestra vestibuli. It consists of three small bones:

- Malleus ("hammer"): **A** Posterior view. **B** Anterior view.
- Incus ("anvil"): **C** Medial view. **D** Anterolateral view.
- Stapes ("stirrup"): **E** Superior view. **F** Medial view.

Note the synovial joint articulations between the malleus and incus (articulatio incudomallearis) and the incus and stapes (articulatio incudostapedalis).

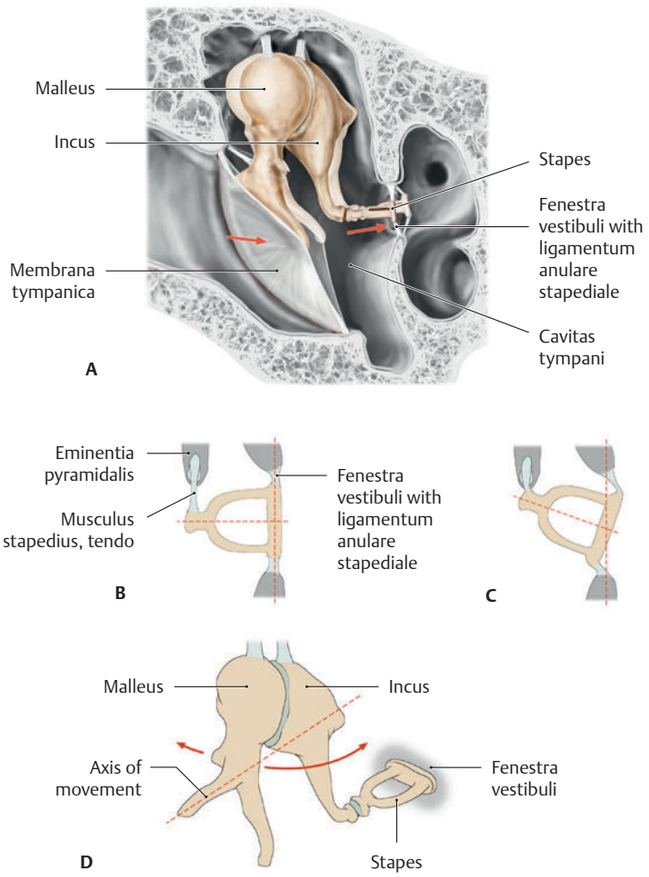


Fig. 10.15 **Function of the ossicular chain**
Anterior view.

A Sound waves (periodic pressure fluctuations in the air) set the membrana tympanica into vibration. The ossicular chain transmits the vibrations of the membrana tympanica (and thus the sound waves) to the fenestra vestibuli, which in turn communicates them to an aqueous medium (perilympha). Conductive deafness occurs when there is impaired transmission of sound waves. Although sound waves encounter very little resistance in air, they encounter considerably higher impedance when they reach the fluid interface of the auris interna. The sound waves must therefore be amplified ("impedance matching"). The difference in surface area between the membrana tympanica and fenestra vestibuli increases the sound pressure by a factor of 17. This is augmented by the 1.3-fold mechanical advantage of the lever action of the ossicular chain. Thus, in passing from the membrana tympanica to the auris interna, the sound pressure is amplified by a factor of 22. If the ossicular chain fails to transform the sound pressure between the membrana tympanica and basis stapedis (footplate), the patient will experience conductive hearing loss of magnitude approximately 20 dB.

B, **C** Sound waves impinging on the membrana tympanica induce motion in the ossicular chain, causing a tilting movement of the stapes (**B** normal position, **C** tilted position). The movements of the basis stapedis against the membrane of the fenestra vestibuli (membrana stapedialis) induce corresponding waves in the fluid column in the inner ear.

D The movements of the ossicular chain are essentially rocking movements (the dashed line indicates the axis of the movements, the arrows indicate their direction). Two muscles affect the mobility of the ossicular chain: the musculus tensor tympani and the musculus stapedius (see **Fig. 10.16**).

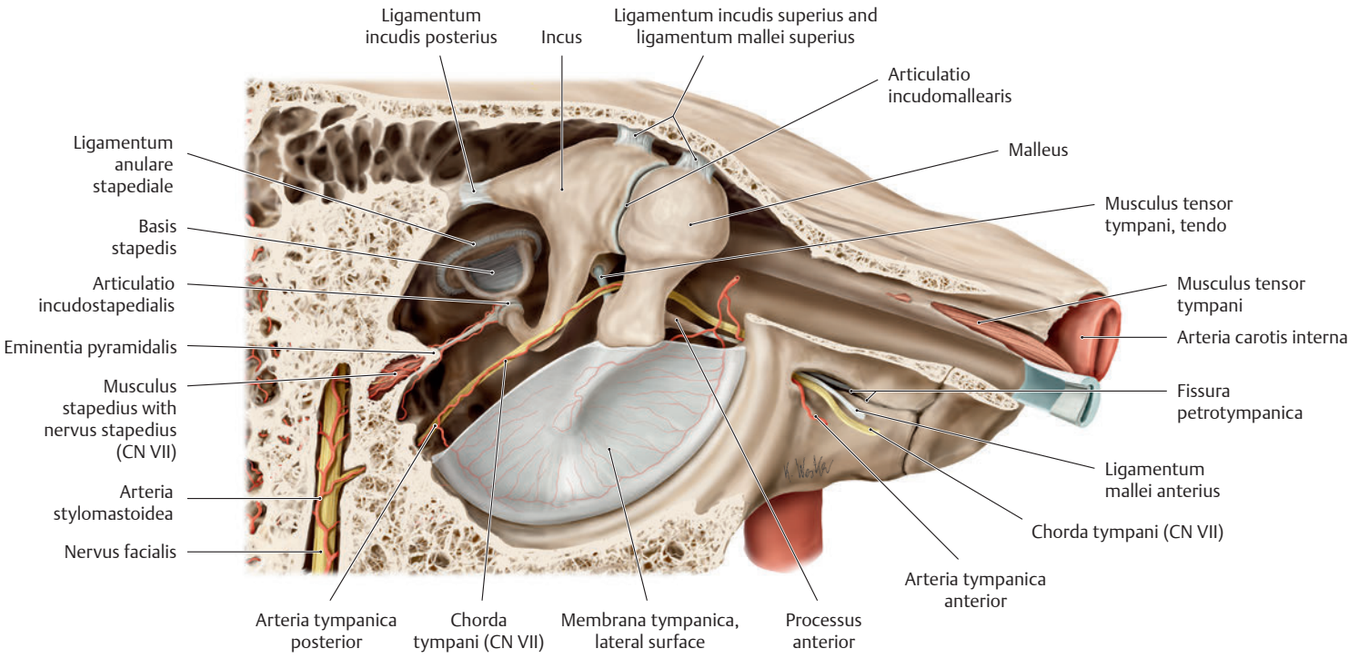


Fig. 10.16 **Ossicular chain in the cavitas tympani**
Lateral view of the right ear. The joints and their stabilizing ligaments can be seen with the two muscles of the auris media—the musculi stapedius and tensor tympani. The *musculus stapedius* (innervated by the nervus stapedius branch of the nervus facialis) inserts on the stapes. When it contracts, it stiffens the sound conduction apparatus and dampens sound transmission to the auris interna. This filtering function is believed to be particularly important at high sound frequencies ("high-pass filter"). When sound is transmitted into the auris media through a probe placed in the meatus acusticus externa, one can measure the action of the musculus stapedius (stapedius reflex test, p. 277) by measuring the change in acoustic impedance (i.e., the amplification of the sound waves). Contraction of the *musculus tensor tympani* (innervated by the nervus trigeminus CN V_3 via the nevus pterygoideus medialis) stiffens the membrana tympanica, thereby reducing the transmission of sound. Both muscles undergo a reflex contraction in response to loud acoustic stimuli. *Note:* The chorda tympani (from CN VII) passes through the auris media without a bony covering (making it susceptible to injury during otological surgery).

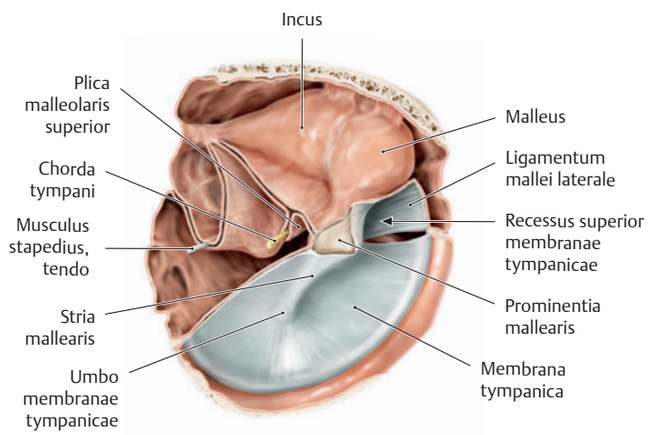


Fig. 10.17 **Mucosal lining of the cavitas tympani**
Posterolateral view with the membrana tympanica partially removed. The cavitas tympani and the structures it contains (ossicular chain, tendons, nerves) are covered with mucosa. The epithelium consists mainly of a simple squamous type, with areas of ciliated columnar cells and goblet cells. Because the cavitas tympani communicates directly with the respiratory tract (pars nasalis pharyngis) through the tuba auditiva, it can also be interpreted as a specialized paranasal sinus. Like the sinuses, it is susceptible to frequent infections (otitis media), which may cause ear pain, a hearing deficit, a purulent discharge from the ear, and balance problems.

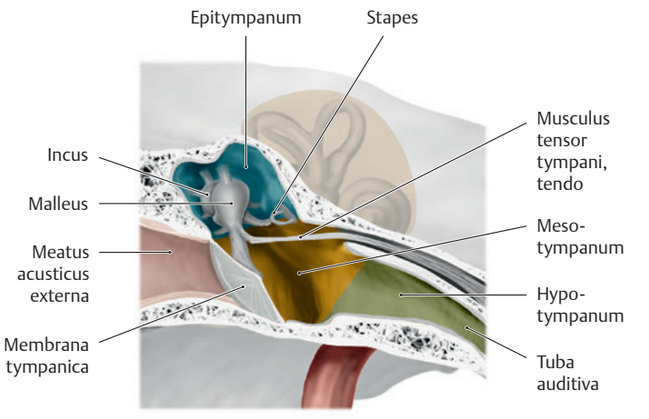


Fig. 10.18 **Clinically important levels of the cavitas tympani**
The cavitas tympani is divided into three levels in relation to the membrana tympanica:

- Epitympanum (recessus epitympanicus, attic) above the membrana tympanica
- Mesotympanum medial to the membrana tympanica
- Hypotympanum (hypotympanic recess) below the membrana tympanica

The epitympanum communicates with the cellulae mastoideae, and the hypotympanum communicates with the tuba auditiva.

Auris Interna (I): Overview & Innervation (CN VIII)

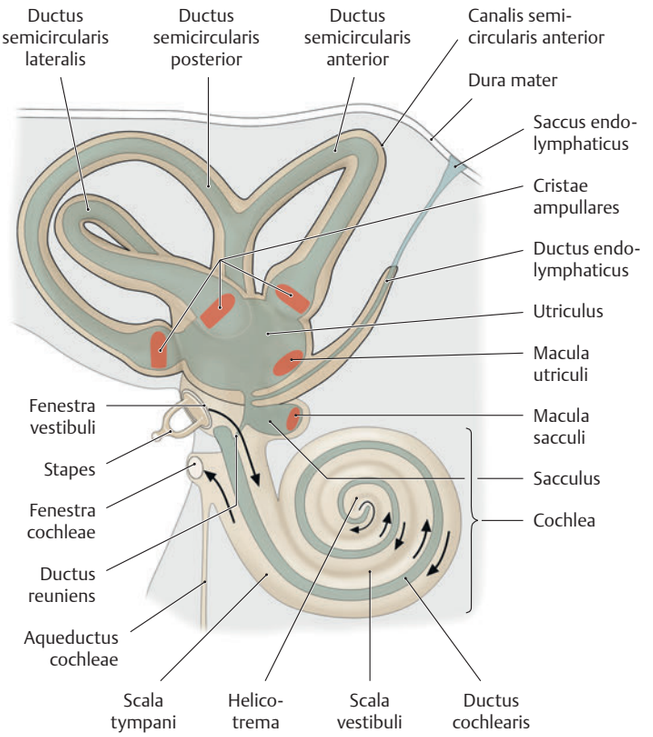


Fig. 10.19 **Auris interna**
The auris interna, embedded within the pars petrosa ossis temporalis, is formed by a labyrinthus membranaceus, which floats within a similarly shaped labyrinthus osseus, loosely attached by connective tissue fibers. **Labyrinthus membranaceus (blue):** The labyrinthus membranaceus is filled with endolympha. This spatium endolymphaticum (blue) communicates with the saccus endolymphaticus, an epidural pouch on the posterior surface of the pars petrosa, via the ductus endolymphaticus. *Note:* The auditory and vestibular spatia endolymphatica are connected by the ductus reuniens. **Labyrinthus osseus (beige):** The labyrinthus osseus is filled with perilympha. This spatium perilymphaticum (beige) is connected to the subarachnoid space by the aqueductus cochleae (perilymphatic duct), which ends at the posterior surface of the pars petrosa ossis temporalis, inferior to the meatus acusticus internus.
The auris media contains the auditory apparatus (hearing) and the vestibular apparatus (balance). **Auditory apparatus** (see pp. 274–275): The sensory epithelium of the auditory apparatus (organum spirale, organ of Corti) is found in the cochlea. The cochlea consists of the membranous ductus cochlearis and bony labyrinthus cochlearis. Damage to the cochlea or nervus cochlearis, which combines with the nervus vestibularis to form CN VIII, leads to sensorineural deafness. **Vestibular apparatus** (see pp. 278–279): The sensory epithelium of the vestibular apparatus is found in the sacculus, the utriculus, and the three membranous ductus semicircularis. The sacculus and utriculus are enclosed in the bony vestibulum, and the ducts are enclosed in bony canales semicirculares.

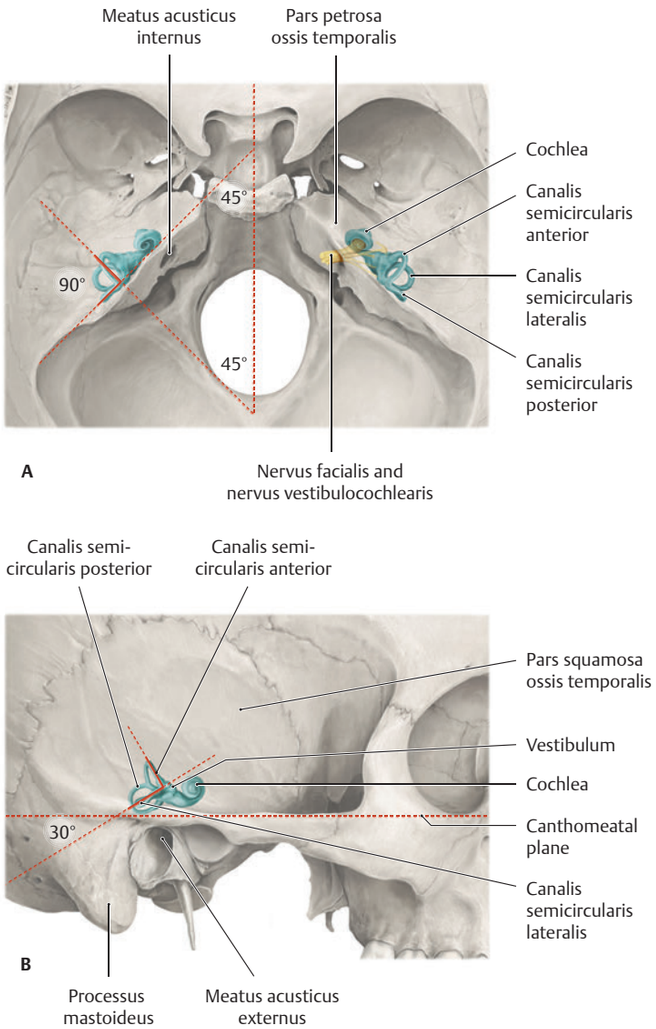


Fig. 10.20 **Projection of the auris interna onto the bony skull**
A Superior view of the pars petrosa ossis temporalis. **B** Right lateral view of the pars squamosa ossis temporalis.
The apex of the cochlea is directed anteriorly and laterally—not upward as one might intuitively expect. The bony canales semicirculares are oriented at an approximately 45-degree angle to the cardinal body planes (coronal, transverse, and sagittal). It is important to know this arrangement when interpreting thin-slice CT scans of the pars petrosa. *Note:* The location of the canales semicirculares is of clinical importance in thermal function tests of the vestibular apparatus. The canalis semicircularis lateralis (horizontal) is directed 30 degrees forward and upward. If the head of the *supine* patient is elevated by 30 degrees, the canalis semicircularis lateralis will assume a vertical alignment. Because warm fluids tend to rise, irrigating the meatus acusticus externus with warm (44° C) or cool (30° C) water (relative to the normal body temperature) can induce a thermal current in the endolympha of the canalis semicircularis, causing the patient to manifest vestibular nystagmus (jerky eye movements, vestibulo-ocular reflex). Because head movements always stimulate both vestibular apparatuses, caloric testing is the only method of *separately* testing the function of each vestibular apparatus (important in the diagnosis of unexplained vertigo).

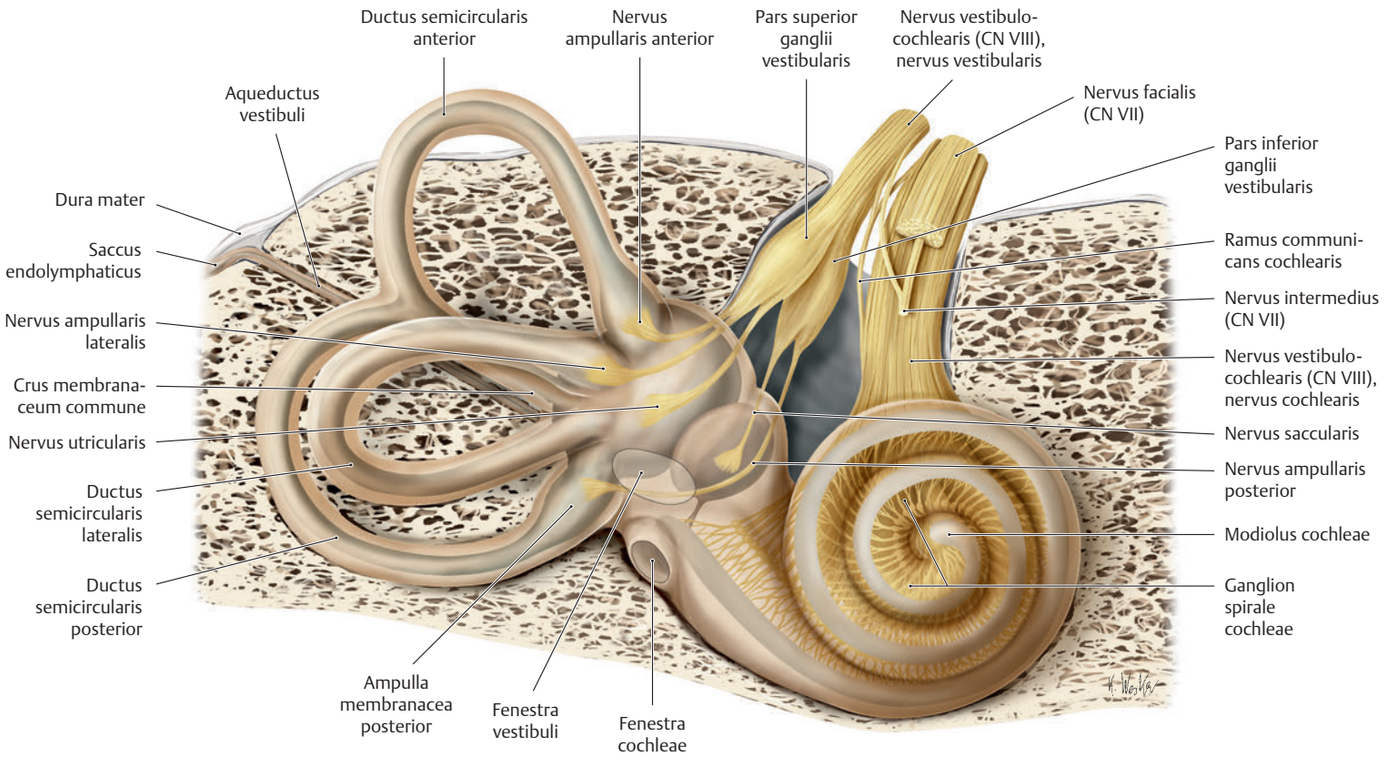


Fig. 10.21 **Innervation of the labyrinthus membranaceus**
Right ear, anterior view. Afferent impulses from the labyrinthi membranacei vestibularis and cochlearis are relayed via dentritic processes to cell bodies in the *ganglia vestibulare* and *spirale*, respectively. The central processes of the ganglia vestibulare and spirale form the nervus vestibularis and cochlearis of the nervus vestibulocochlearis (CN VIII), respectively (see pp. 134–135 for a full discussion of CN VIII). CN VIII relays afferent impulses to the truncus encephali through the meatus acusticus internus and angulus pontocerebellaris. *Ganglion vestibulare:* The cell bodies of afferent neurons (bipolar ganglion cells) in the pars superior ganglii vestibularis receive afferent impulses from the canalis semicircularis anterior and lateralis and the sacculus; cell bodies in the pars inferior receive afferent impulses from the canalis semicircularis posterior and utriculus. *Ganglia spiralia:* Located in the central bony core of the cochlea (modiolus cochleae), the cell bodies of bipolar ganglion cells in the ganglia spiralia receive afferent impulses from the auditory apparatus via their dendritic processes.

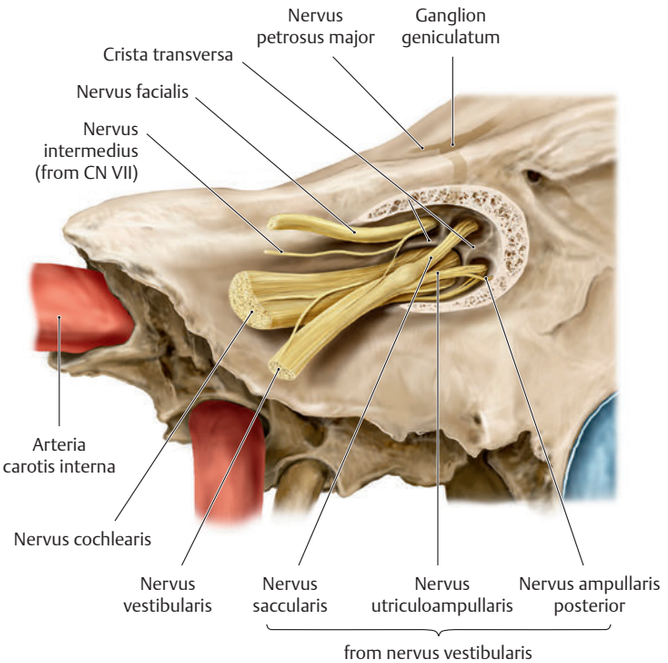


Fig. 10.22 **Nervi craniales in the right meatus acusticus internus**
Posterior oblique view of the fundus of the meatus acusticus internus. The approximately 1-cm-long meatus acusticus internus begins at the porus acusticus internus on the posterior wall of the pars petrosa ossis temporalis. It contains:

- Nervus vestibulocochlearis (CN VIII) with its nervus cochlearis and nervus vestibularis parts
- Nervus facialis (CN VII), along with its parasympathetic and taste fibers (nervus intermedius)
- Arteria labyrinthi and venae labyrinthi (not shown)

Given the close proximity of the nervus vestibulocochlearis and nervus facialis in the bony canal, a tumor of the nervus vestibulocochlearis (*acoustic neuroma*) may exert pressure on the nervus facialis, leading to peripheral facial paralysis. Acoustic neuroma is a benign tumor that originates from the Schwann cells of vestibular fibers, so it would be more accurate to call it a *vestibular schwannoma*. Tumor growth always begins in the meatus acusticus internus; as the tumor enlarges, it may grow into the angulus pontocerebellaris (see p. 134). Acute, unilateral inner ear dysfunction with hearing loss (sudden sensorineural hearing loss), often accompanied by tinnitus (ringing in the ears), typically reflects an underlying vascular disturbance (vasospasm of the arteria labyrinthi causing decreased blood flow).

Arteries & Veins of the Auris Media & Interna

The structures of the auris externa and media are supplied primarily by branches of the arteria carotis externa. (*Note:* The arteriae caroticotympanicae arise from the arteria carotis interna.) The inner ear is supplied by the arteria labyrinthi, which arises from the arteria basilaris. Venous drainage of the auricula is to the venae temporales superficiales (via venae auriculares), whereas drainage of the auris externa is to the venae jugularis externa and maxillaris and the plexus pterygoideus. The veins of the cavitas tympani drain to the plexus pterygoideus and sinus petrosus superior; the auris interna drains to the venae labyrinthi, which empties into the sinus petrosus superior or sinus transversus.

Table 10.1 **Arteries of the ear**

Artery	Origin	Distribution
Arteriae caroticotympanicae	Arteria carotis interna	Tuba auditiva and paries caroticus of cavitas tympani
Arteria stylomastoidea	Arteria auricularis posterior or arteria occipitalis	Cavitas tympani, cellulae mastoideae and antrum mastoideum, musculus stapedius, stapes
Arteria tympanica inferior	Arteria pharyngea ascendens	Paries labyrinthicus of cavitas tympani, promontorium
Arteria auricularis profunda	Arteria maxillaris	External surface of membrana tympanica
Arteria tympanica posterior	Arteria stylomastoidea	Chorda tympani, membrana tympanica, malleus
Arteria tympanica superior	Arteria meningea media	Musculus tensor tympani, paries tegmentalis of cavitas tympani, stapes
Arteria tympanica anterior	Arteria maxillaris	Membrana tympanica, antrum mastoideum, malleus, incus
Arteria tubalis	Arteria pharyngea ascendens	Tuba auditiva and anterior cavitas tympani
Tympanic branches	Arteria canalis pterygoidei	Cavitas tympani and tuba auditiva
Ramus petrosus	Arteria meningea media	Nervus facialis in canalis nervi facialis and cavitas tympani
Arteria labyrinthi (arteria auditoria interna)	Arteria basilaris directly or via arteria inferior anterior cerebelli	Cochlea and vestibular system

Note: The arteries supplying the cavitas tympani and its contents form a rich arterial anastomotic network within the auris media. The venous drainage of the auris media is primarily into the plexus pterygoideus of veins located in the fossa infratemporalis or into sinus durae matris.

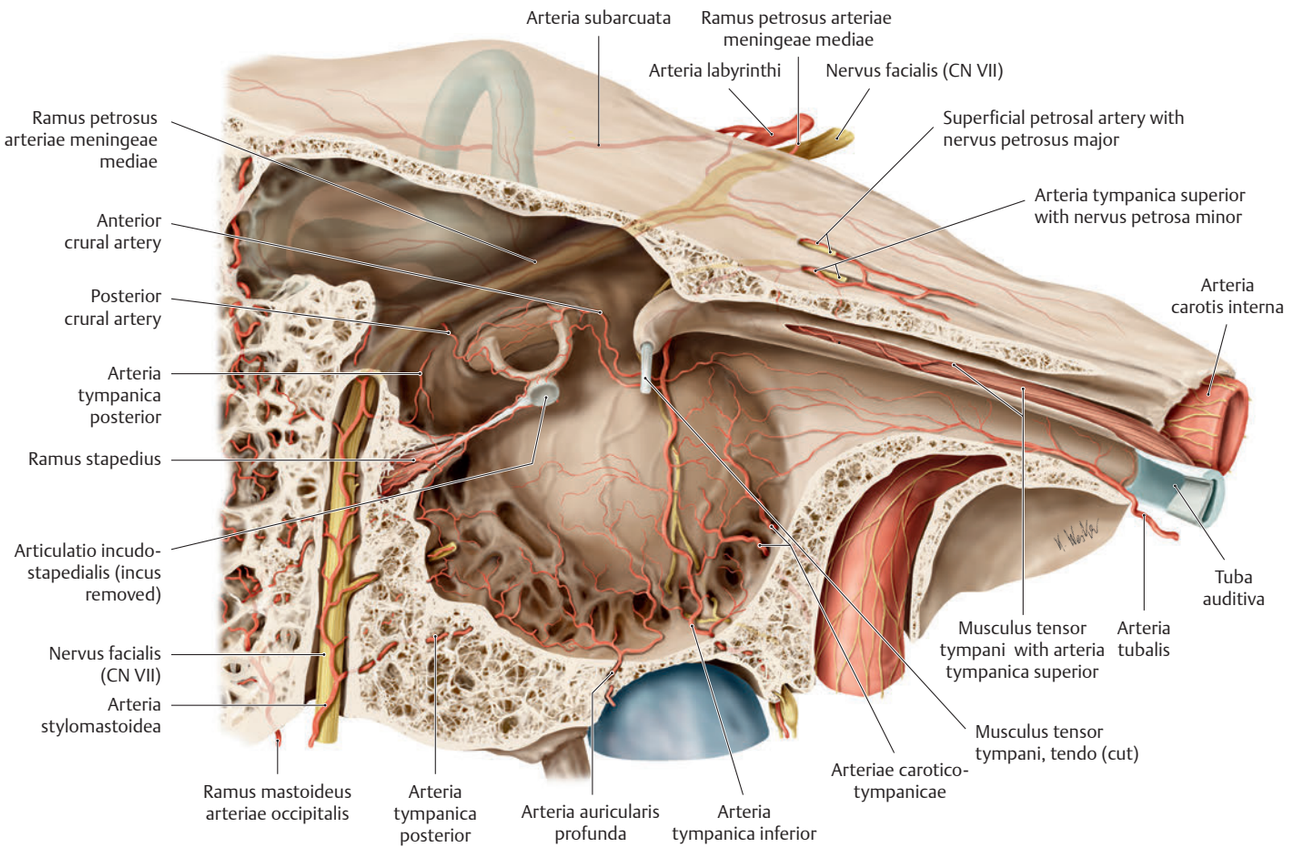


Fig. 10.23 **Arteries of the cavitas tympani and cellulae mastoideae**
Pars petrosa ossis temporalis, anterior view. The malleus, incus, chorda tympani, and arteria tympanica anterior have been removed (see **Fig. 10.24**).

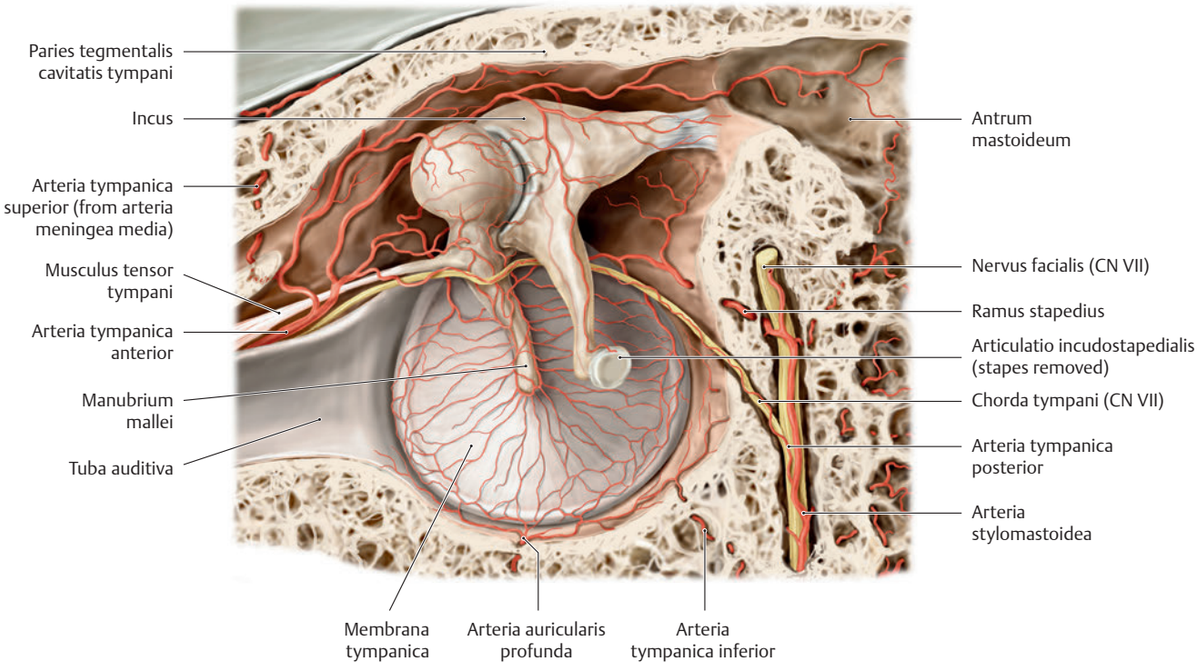


Fig. 10.24 **Arteries of the ossicular chain and membrana tympanica**

Medial view of the right membrana tympanica (see **Fig. 10.13** for orientation). This region receives most of its blood supply from the arteria tympanica anterior. With inflammation of the membrana tympanica, the arteries may become so dilated that their course in the membrana tympanica can be seen, as illustrated here.

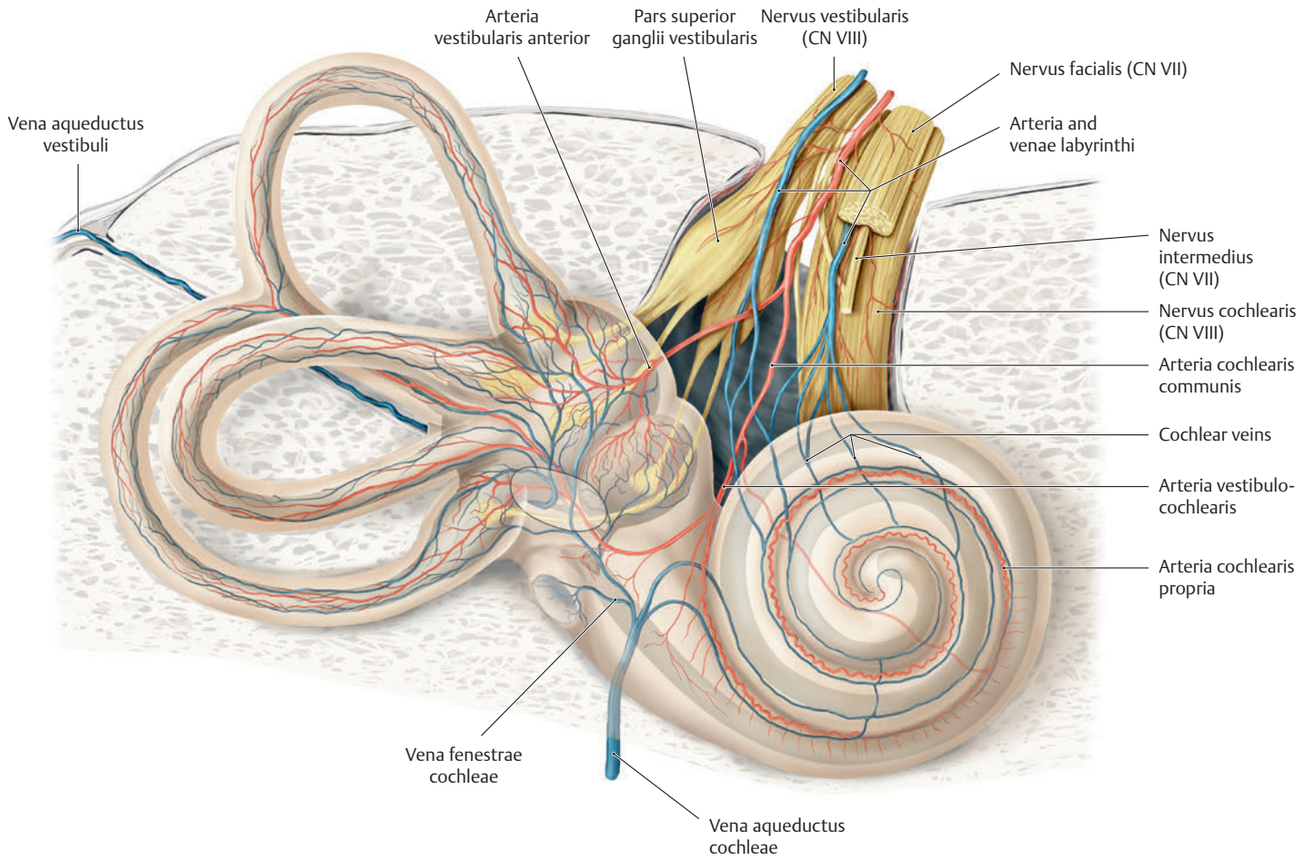


Fig. 10.25 **Arteries and veins of the auris interna**

Right anterior view. The labyrinthus receives its arterial blood supply from the arteria labyrinthi, which generally arises directly from the arteria basilaris, but may arise from the arteria inferior anterior cerebelli. Venous blood drains to the vena labyrinthi and into the sinus petrosus inferior or the sinus transversus.

Auris Interna (II): Auditory Apparatus

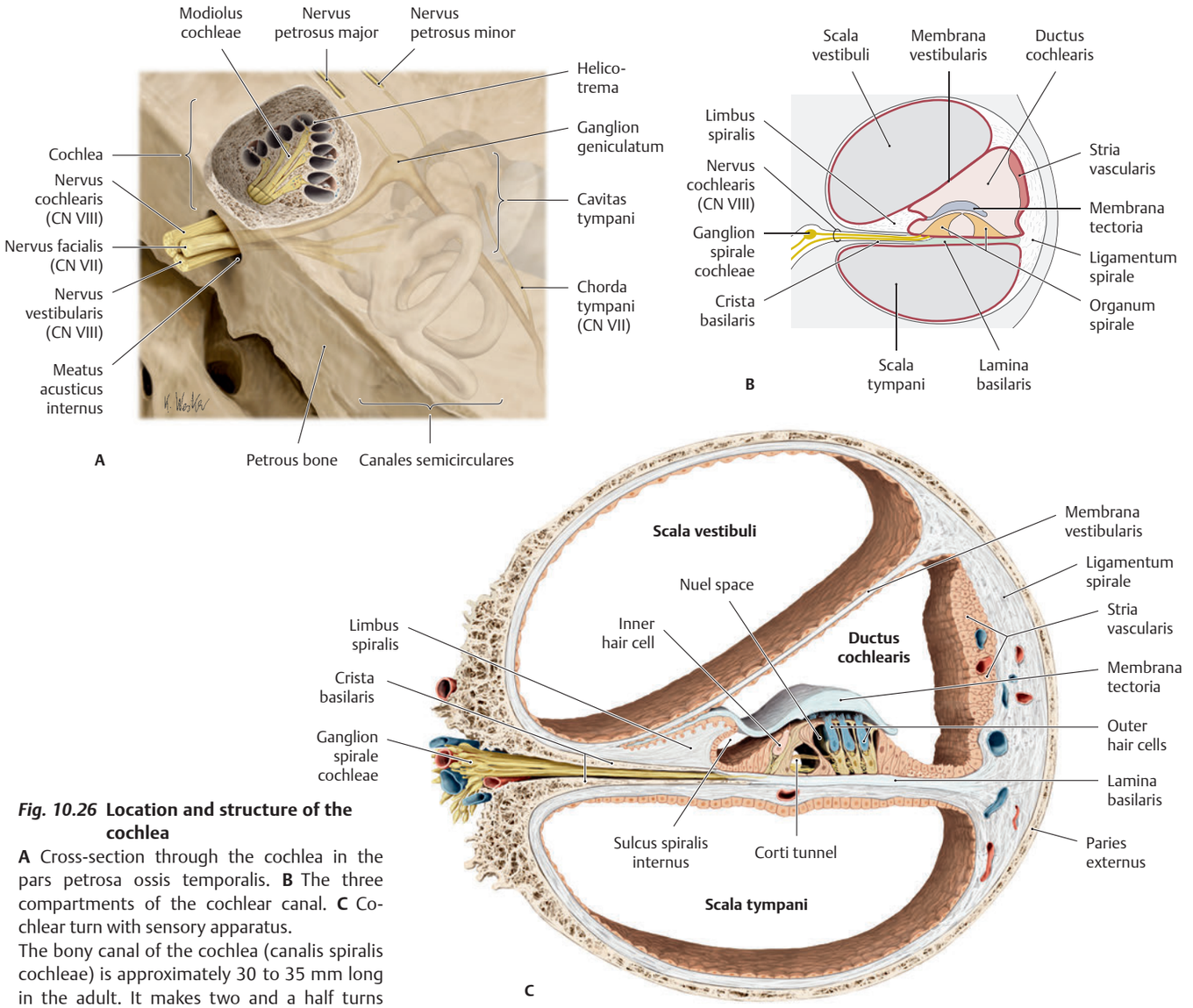


Fig. 10.26 **Location and structure of the cochlea**

A Cross-section through the cochlea in the pars petrosa ossis temporalis. **B** The three compartments of the cochlear canal. **C** Cochlear turn with sensory apparatus.

The bony canal of the cochlea (canalis spiralis cochleae) is approximately 30 to 35 mm long in the adult. It makes two and a half turns around its bony axis, the *modiolus cochleae,* which is permeated by branched cavities and contains the ganglion spirale cochleae (perikarya of the afferent neurons). The basis cochleae is directed toward the meatus acusticus internus (**A**). A cross-section through the canalis spiralis cochleae displays three membranous compartments arranged in three levels (**B**). The upper and lower compartments, the *scala vestibuli* and *scala tympani,* each contain perilympha; the middle level, the *ductus cochlearis* (scala media), contains endolympha. The spatia perilymphatica are interconnected at the apex by the *helicotrema,* and the spatium endolymphaticum ends blindly at the apex. The ductus cochlearis, which is triangular in cross-section, is separated from the scala vestibuli by the *membrana vestibularis* and from the scala tympani by the *membrana spiralis*. The lamina basilaris represents a bony projection of the modiolus (*lamina spiralis ossea*) and widens steadily from the base of the cochlea to the apex. High frequencies (up to 20,000 Hz) are perceived by the narrow portions of the lamina basilaris, whereas low frequencies (down to about 200 Hz) are perceived by its broader portions (*tonotopic organization*). The lamina basilaris and lamina spiralis ossea thus form the floor of the ductus cochlearis, upon which the actual organ of hearing, the organum spirale (organ of Corti), is located. This organ consists of a system of sensory cells and supporting cells covered by an acellular gelatinous flap, the *membrana tectoria*. The sensory cells (inner and outer hair cells) are the receptors of the orgnaum spirale (**C**). These cells bear approximately 50 to 100 stereocilia, and on their apical surface synapse on their basal side with the endings of afferent and efferent neurons. They have the ability to transform mechanical energy into electrochemical potentials. A magnified cross-sectional view of a cochlear turn (**C**) also reveals the *stria vascularis,* a layer of vascularized epithelium in which the endolympha is formed. This endolympha fills the labyrinthus membranaceus (appearing here as the ductus cochlearis, which is part of the labyrinthus osseus). The organum spirale is located on the lamina basilaris. It transforms the energy of the acoustic traveling wave into electrical impulses, which are then carried to the brain by the nervus cochlearis. The principal cell of signal transduction is the inner hair cell. The function of the lamina basilaris is to transmit acoustic waves to the inner hair cell, which transforms them into impulses that are received and relayed by the ganglion spirale cochleae.

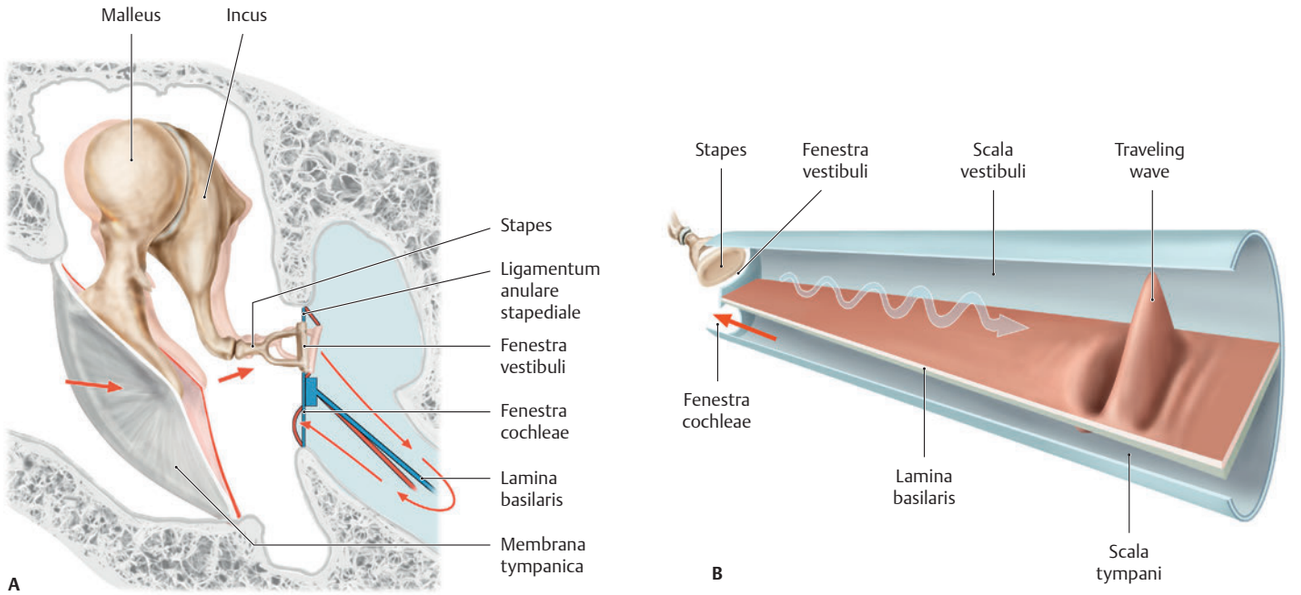


Fig. 10.27 **Sound conduction during hearing**

A Sound conduction from the auris media to the auris interna: Sound waves in the air deflect the membrana tympanica, whose vibrations are conducted by the ossicular chain to the fenestra vestibuli. The sound pressure induces motion of the fenestra vestibuli membrane, whose vibrations are, in turn, transmitted through the perilympha to the lamina basilaris of the auris interna (see **B**). The fenestra cochleae equalizes pressures between the auris media and interna.

B Formation of a traveling wave in the cochlea: The sound wave begins at the fenestrum vestibuli and travels up the scala vestibuli to the apex of the cochlea ("traveling wave"). The amplitude of the traveling wave gradually increases as a function of the sound frequency and reaches a maximum value at particular sites (shown greatly exaggerated in the drawing). These are the sites where the receptors of the organum spirale are stimulated and signal transduction occurs. To understand this process, one must first grasp the structure of the organum spirale (the actual organ of hearing), which is depicted in **Fig. 10.28**.

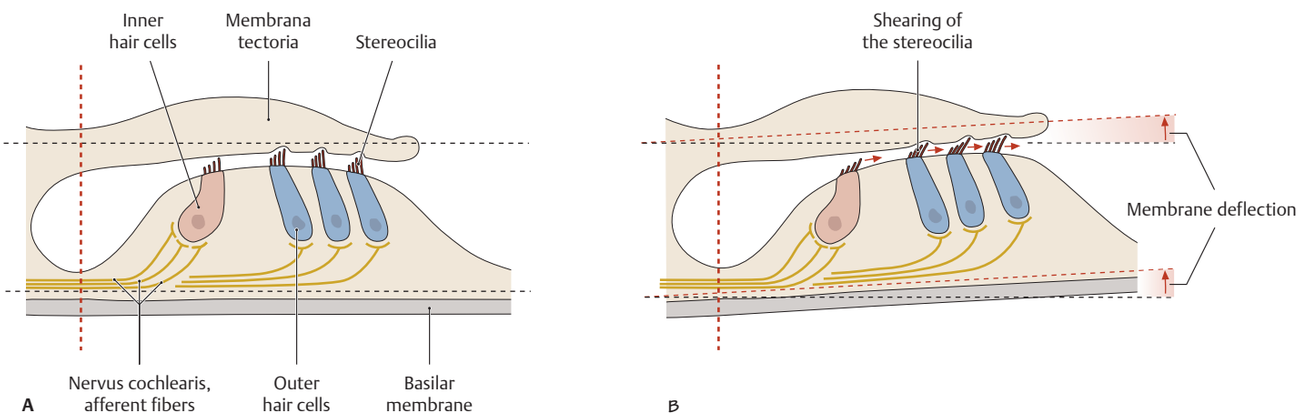


Fig. 10.28 **Organum spirale at rest (A) and deflected by a traveling wave (B)**

The traveling wave is generated by vibrations of the fenestra vestibuli membrane. At each site that is associated with a particular sound frequency, the traveling wave causes a maximum deflection of the lamina basilaris and thus of the membrana tectoria, setting up shearing movements between the two membranes. These shearing movements cause the stereocilia on the *outer* hair cells to bend. In response, the hair cells actively change their length, thereby increasing the local amplitude of the traveling wave. This additionally bends the stereocilia of the *inner* hair cells, stimulating the release of glutamate at their basal pole. The release of this substance generates an excitatory potential on the afferent nerve fibers, which is transmitted to the brain.

Auditory Pathway

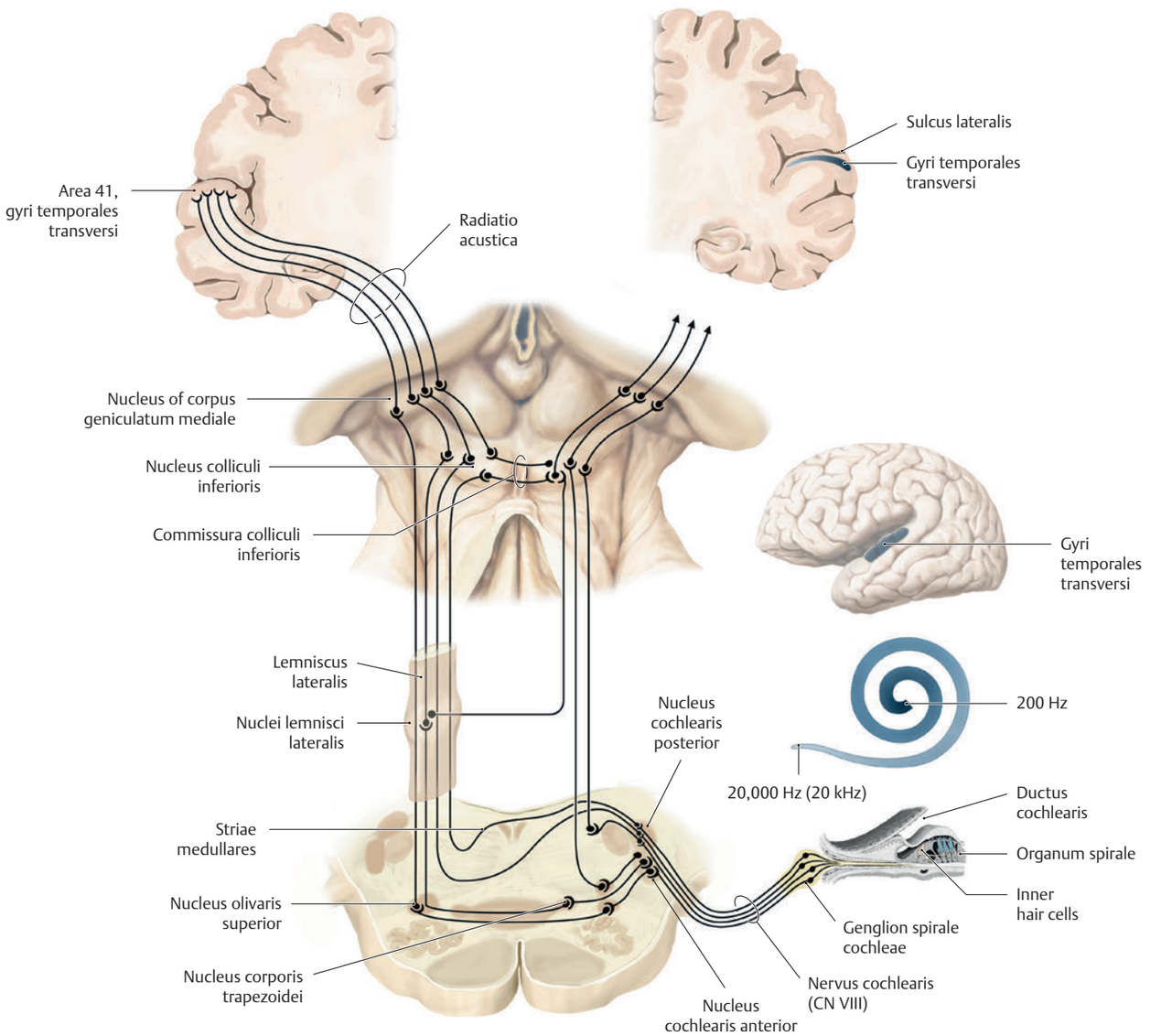


Fig. 10.29 **Afferent auditory pathway of the left ear**
The receptors of the auditory pathway are the inner hair cells of the organum spirale. Because they lack neural processes, they are called *secondary sensory cells.* They are located in the ductus cochlearis of the lamina basilaris and are studded with stereocilia, which are exposed to shearing forces from the membrana tectoria in response to a traveling wave. This causes bowing of the stereocilia (see **Fig. 10.28**). These bowing movements act as a stimulus to evoke cascades of neural signals. Dendritic processes of the bipolar neurons in the ganglion spirale cochleae pick up the stimulus. The bipolar neurons then transmit impulses via their axons, which are collected to form the nervus cochlearis, to the nuclei cochleares anterior and posterior. In these nuclei the signals are relayed to the second neuron of the auditory pathway. Information from the nuclei cochleares is then transmitted via four to six nuclei to the primary auditory cortex, where the auditory information is consciously perceived (analogous to the visual cortex). The primary auditory cortex is located in the gyri temporales transversi (Heschl gyri, Brodmann area 41). The auditory pathway thus contains the following key stations:

- Inner hair cells in the organum spirale
- Ganglion spirale cochleae
- Nuclei cochleares anterior and posterior
- Nucleus corporis trapezoidei and nucleus
- Nucleus lemnisci lateralis
- Nucleus colliculi inferioris
- Nucleus of the corpus geniculatum mediale
- Primary auditory cortex in the lobus temporalis (gyri temporales transversi = Heschl gyri or Brodmann area 41)

The individual parts of the cochlea are correlated with specific areas in the auditory cortex and its relay stations. This is known as the *tonotopic organization of the auditory pathway.* This organizational principle is similar to that in the visual pathway. Binaural processing of the auditory information (= stereo hearing) first occurs at the level of the nucleus olivaris superior. At all further stages of the auditory pathway there are also interconnections between the right and left sides of the auditory pathway (for clarity, these are not shown here). A cochlea that has ceased to function can sometimes be replaced with a cochlear implant.

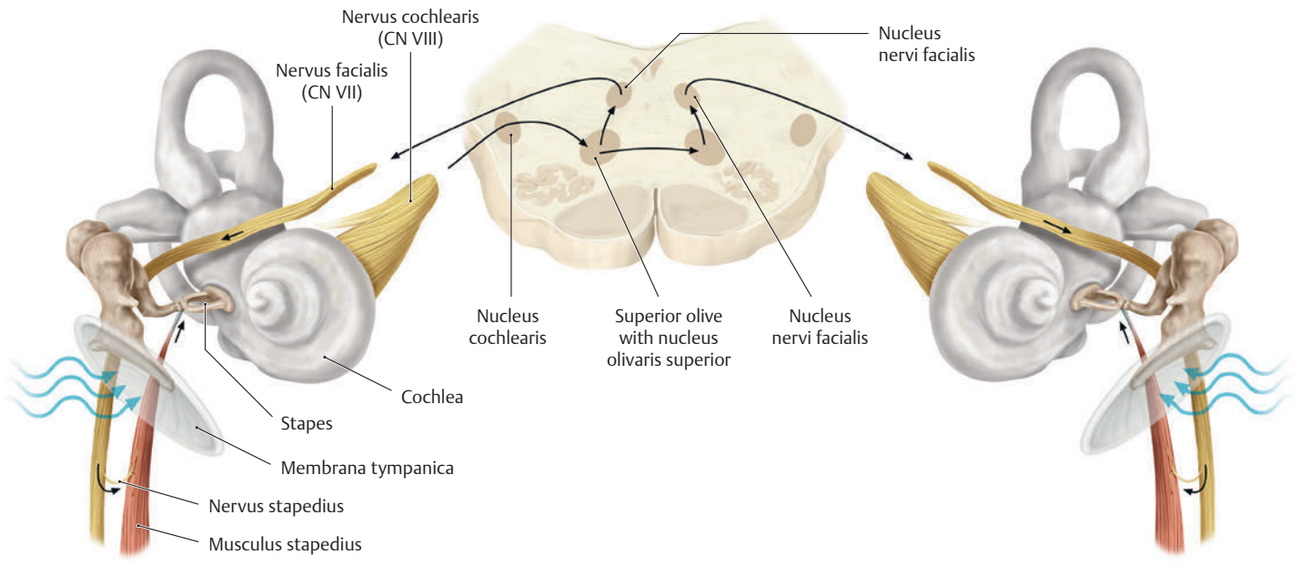


Fig. 10.30 **The stapedius reflex**
When the volume of an acoustic signal reaches a certain threshold, the stapedius reflex triggers a contraction of the musculus stapedius. This reflex can be utilized to test hearing without the patient's cooperation ("objective" auditory testing). The test is done by introducing a sonic probe into the ear canal and presenting a test noise to the membrana tympanica. When the noise volume reaches a certain threshold, it evokes the stapedius reflex, and the membrana tympanica stiffens. The change in the resistance of the membrana tympanica is then measured and recorded. The *afferent* limb of this reflex is in the nervus cochlearis. Information is conveyed to the facial nucleus on each side by way of the nucleus olivaris superior. The *efferent* limb of this reflex is formed by branchiomotor (visceromotor) fibers of the nervus facialis.

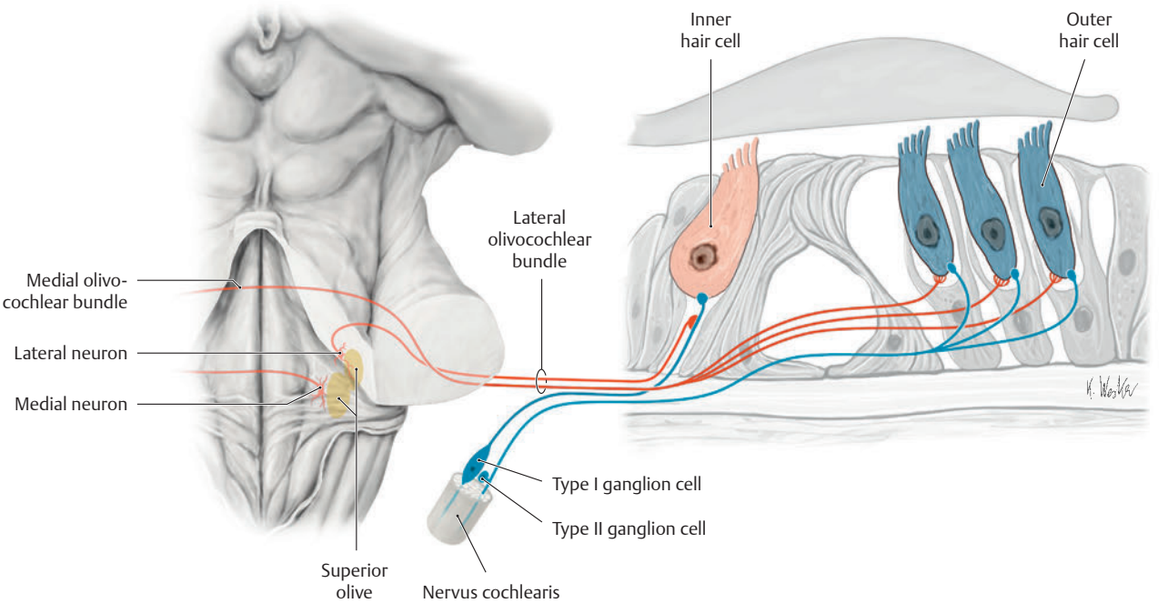


Fig. 10.31 **Efferent fibers from the olive to the organum spirale**
Besides the afferent (sensory) fibers from (blue) the organum spirale, which form the nervus cochlearis, there are also efferent (motor) fibers (red) that pass to the organum spirale in the auris interna and are concerned with the active preprocessing of sound ("cochlear amplifier") and acoustic protection. The efferent fibers arise from neurons that are located in either the lateral or medial part of the superior olive and project from there to the cochlea (lateral or medial olivocochlear bundle). The fibers of the lateral neurons pass *uncrossed* to the dendrites of the *inner* hair cells, whereas the fibers of the medial neurons *cross* to the opposite side and terminate at the base of the *outer* hair cells, whose activity they influence. When stimulated, the outer hair cells can actively amplify the traveling wave. This increases the sensitivity of the inner hair cells (the actual receptor cells). The activity of the efferents from the olive can be recorded as otoacoustic emissions (OAE). This test can be used to screen for hearing abnormalities in newborns.

Auris Interna (III): Vestibular Apparatus

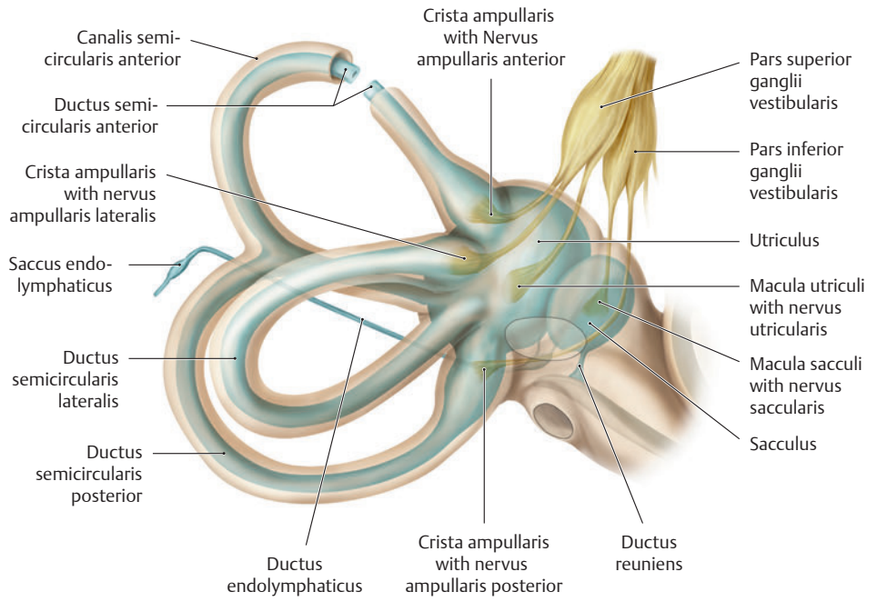


Fig. 10.32 **Structure of the vestibular apparatus**

The vestibular apparatus is the organ of balance. It consists of the membranous ductus semicirculares, which contain sensory ridges (cristae ampullares) in their dilated portions (ampullae), and of the sacculus and utriculus with their macular organs. The sensory organs in the ductus semicirculares respond to angular acceleration; the macular organs, which have an approximately vertical and horizontal orientation, respond to horizontal (macula utriculi) and vertical (macula sacculi) linear acceleration, as well as to gravitational forces.

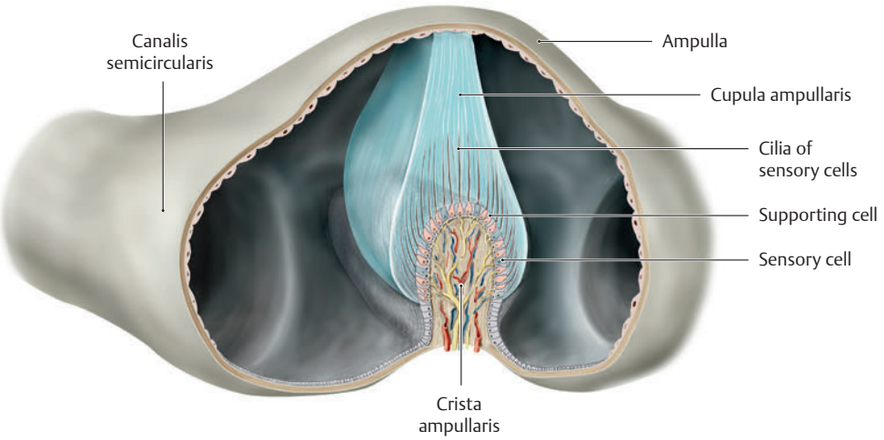


Fig. 10.33 **Structure of the ampulla and crista ampullaris**

Cross-section through the ampulla of a canalis semicircularis. Each canal has a bulbous expansion at one end (ampulla) that is traversed by a connective tissue ridge with sensory epithelium (crista ampullaris). Extending above the crista ampullaris is a gelatinous cupula ampullaris, which is attached to the roof of the ampulla. Each of the sensory cells of the crista ampullaris (approximately 7000 in all) bears on its apical pole one long kinocilium and approximately 80 shorter stereocilia, which project into the cupula ampullaris. When the head is rotated in the plane of a particular canalis semicircularis, the inertial lag of the endolympha causes a deflection of the cupula ampullaris, which in turn causes a bowing of the stereocilia. The sensory cells are either depolarized (excitation) or hyperpolarized (inhibition), depending on the direction of ciliary displacement.

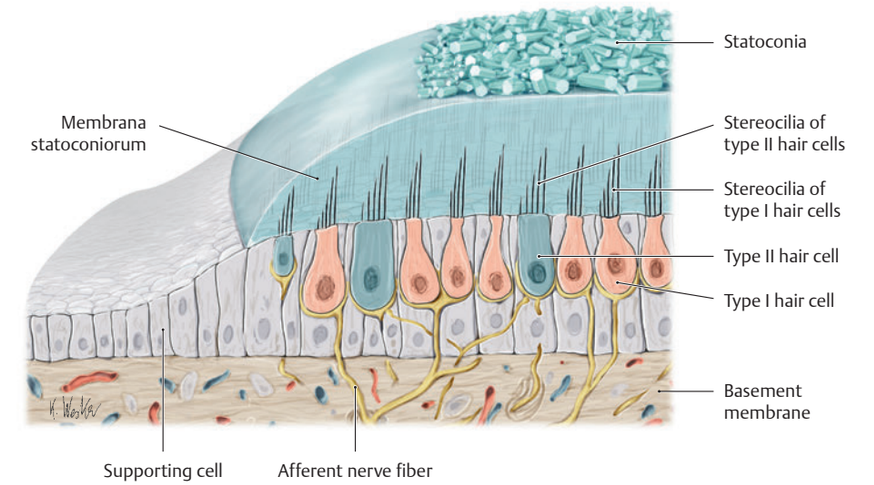


Fig. 10.34 **Structure of the maculae utriculi and sacculi**

The maculae are thickened oval areas in the epithelial lining of the utriculus and sacculus, each averaging 2 mm in diameter and containing arrays of sensory and supporting cells. Like the sensory cells of the crista ampullaris, the sensory cells of the macular organs bear specialized stereocilia, which project into an otolithic membrane (membrana statoconiorum). The latter consists of a gelatinous layer, similar to the cupula ampullaris, but it has calcium carbonate crystals or statoconia (*statoliths*) embedded in its surface. With their high specific gravity, these crystals exert traction on the gelatinous mass in response to linear acceleration, and this induces shearing movements of the cilia. The sensory cells are either depolarized or hyperpolarized by the movement, depending on the orientation of the cilia. There are two distinct categories of vestibular hair cells (type I and type II); type I cells (light red) are goblet shaped.

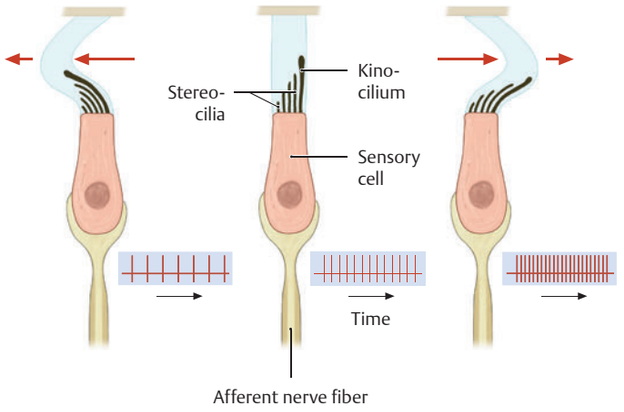


Fig. 10.35 **Stimulus transduction in the vestibular sensory cells**
Each of the sensory cells of the maculae and crista ampullaris bears on its apical surface one long kinocilium and approximately 80 stereocilia of graduated lengths, forming an array that resembles a pipe organ. This arrangement results in a polar differentiation of the sensory cells. The cilia are straight while in a resting state. When the stereocilia are deflected toward the kinocilium, the sensory cell depolarizes, and the frequency of action potentials (discharge rate of impulses) is increased (right side of diagram). When the stereocilia are deflected away from the kinocilium, the cell hyperpolarizes, and the discharge rate is decreased (left side of diagram). This mechanism regulates the release of the transmitter glutamate at the basal pole of the sensory cell, thereby controlling the activation of the afferent nerve fiber (depolarization stimulates glutamate release, and hyperpolarization inhibits it). In this way the brain receives information on the magnitude and direction of movements and changes of position.

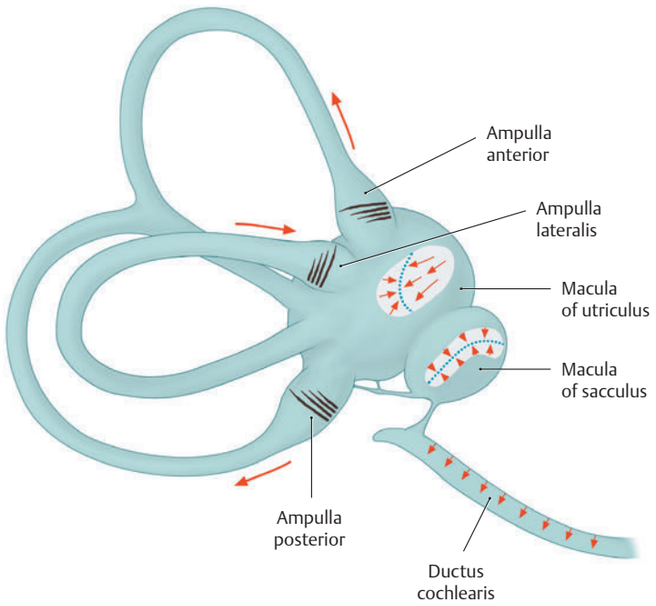


Fig. 10.36 **Specialized orientations of the stereocilia in the vestibular apparatus (cristae ampullares and maculae)**
Because the stimulation of the sensory cells by deflection of the stereocilia *away from* or *toward* the kinocilium is what initiates signal transduction, the spatial orientation of the cilia must be specialized to ensure that every position in space and every movement of the head stimulates or inhibits certain receptors. The ciliary arrangement shown here ensures that every direction in space will correlate with the maximum sensitivity of a particular receptor field. The arrows indicate the polarity of the cilia (i.e., each of the arrowheads points in the direction of the kinocilium in that particular field).
Note that the sensory cells show an opposite, reciprocal arrangement in the sensory fields of the utriculus and sacculus.

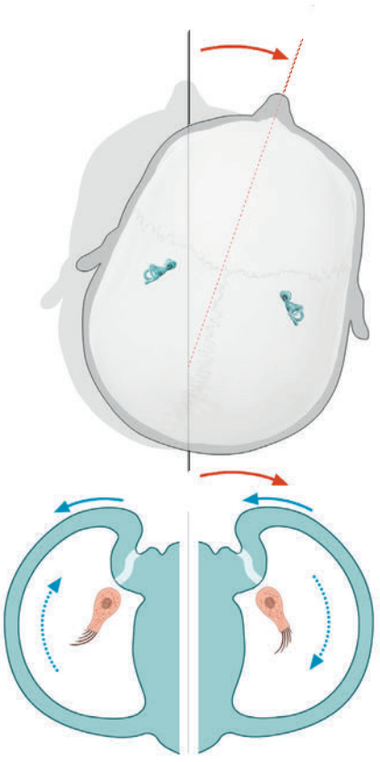


Fig. 10.37 **Interaction of contralateral canales semicirculares during head rotation**
When the head rotates to the right (red arrow), the endolympha flows to the left because of its inertial mass (solid blue arrow, taking the head as the reference point). Owing to the alignment of the stereocilia, the left and right canales semicirculares are stimulated in opposite fashion. On the right side, the stereocilia are deflected toward the kinocilium (dotted arrow; the discharge rate increases). On the left side, the stereocilia are deflected away from the kinocilium (dotted arrow; the discharge rate decreases). This arrangement heightens the sensitivity to stimuli by increasing the stimulus contrast between the two sides. In other words, the difference between the decreased firing rate on one side and the increased firing rate on the other side enhances the perception of the kinetic stimulus.

Vestibular Pathway

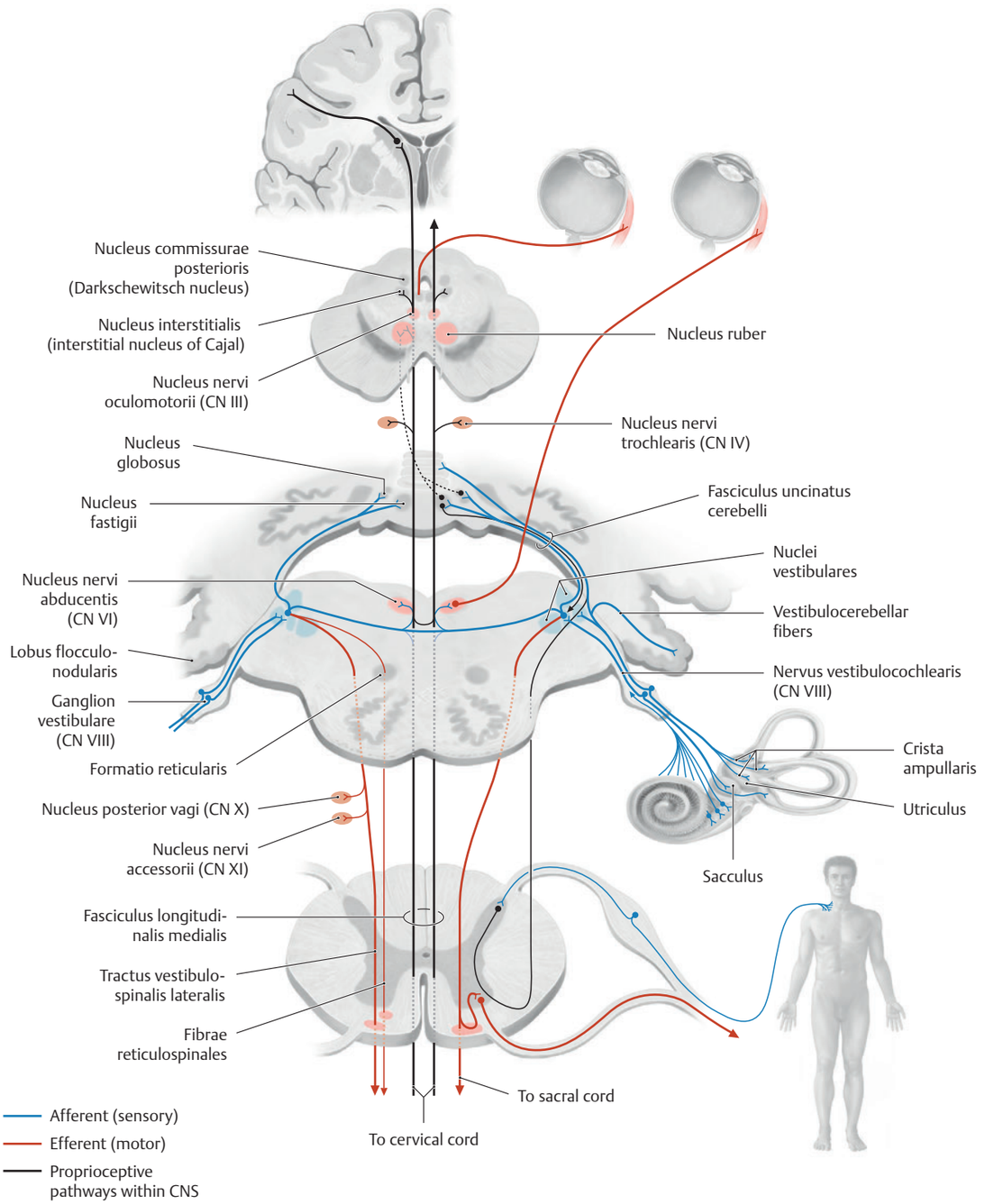


Fig. 10.38 **Central connections of the nervus vestibularis (CN VIII)**
Three systems are involved in the regulation of human balance:

- Vestibular system
- Proprioceptive system
- Visual system

The peripheral receptors of the *vestibular system* are located in the labyrinthus membranaceus, which consists of the utriculus and sacculus and the ampullae of the three ductus semicirculares. The maculae of the utriculus and sacculus respond to linear acceleration, and the ductus semicircularis organs in the cristae ampullares respond to angular (rotational) acceleration. Like the hair cells of the inner ear, the receptors of the vestibular system are *secondary* sensory cells. The basal portions of the secondary sensory cells are surrounded by dendritic processes of bipolar neurons. Their perikarya are located in the ganglion vestibulare. The axons from these neurons form the nervus vestibularis and terminate in the four nuclei vestibulares. Besides input from the vestibular apparatus, these nuclei also receive sensory input (see **Fig. 10.39**). The nuclei vestibulares show a topographical organization (see **Fig. 10.40**) and distribute their efferent fibers to three targets:

- Motor neurons in the medulla spinalis via the tractus vestibulospinalis lateralis. These motor neurons help to maintain an upright stance, mainly by increasing the tone of extensor muscles.
- Lobus flocculonodularis of the cerebellum (archicerebellum) via vestibulocerebellar fibers.
- Ipsilateral and contralateral oculomotor nuclei via the ascending part of the fasciculus longitudinalis medialis.

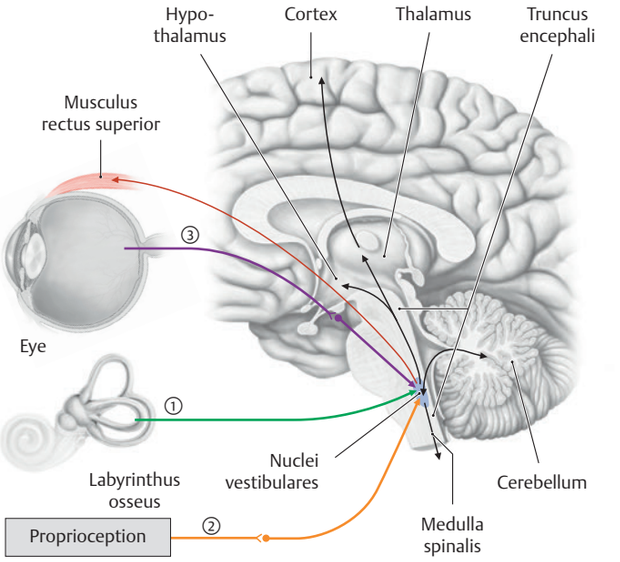


Fig. 10.39 **Role of the nuclei vestibulares in the maintenance of balance**

The nuclei vestibulares receive afferent input from the vestibular system ①, proprioceptive system ② (position sense, muscles, and joints), and visual system ③. They then distribute efferent fibers to nuclei that control the motor systems important for balance. These nuclei are located in the:

- Medulla spinalis (motor support)
- Cerebellum (fine control of motor function)
- Truncus encephali (oculomotor nuclei for oculomotor function)

Efferents from the nuclei vestibulares are also distributed to the following regions:

- Thalamus and cortex (spatial sense)
- Hypothalamus (autonomic regulation: vomiting in response to vertigo)

Note: Acute failure of the vestibular system is manifested by rotary vertigo.

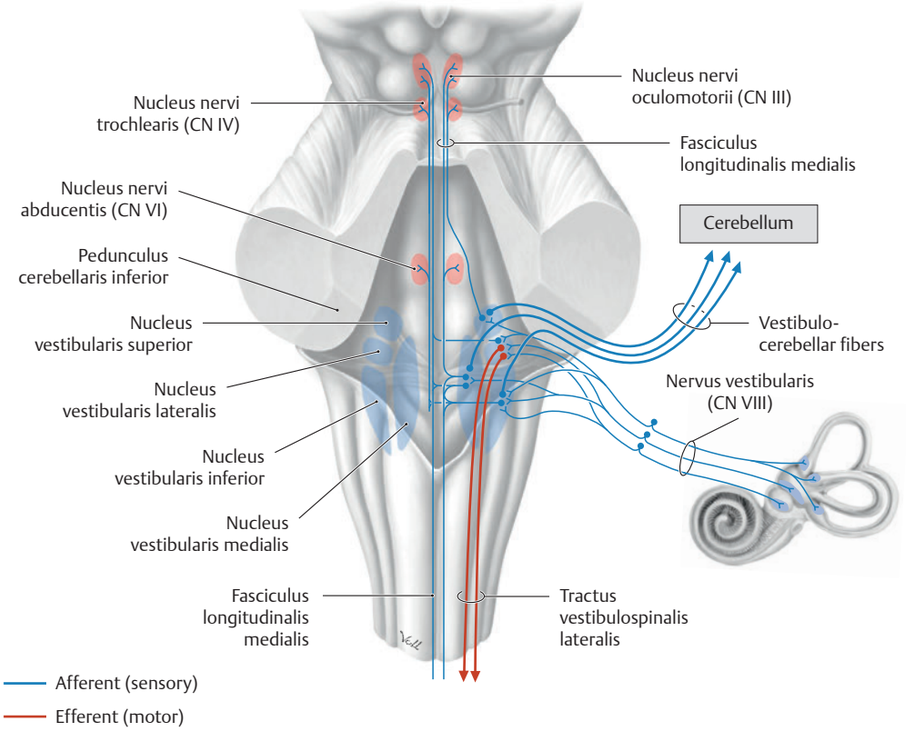


Fig. 10.40 **Nuclei vestibulares: topographic organization and central connections**

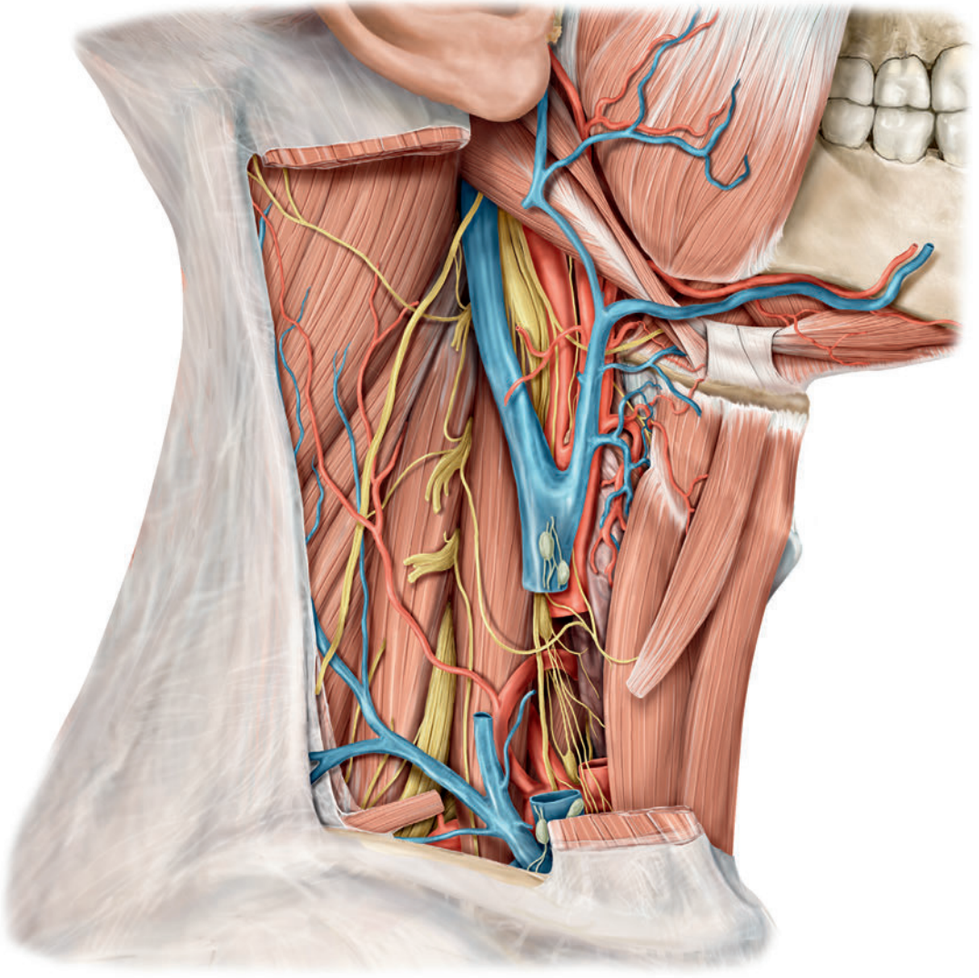
Four nuclei are distinguished:

- Nucleus vestibularis superior (of Bechterew)
- Nucleus vestibularis lateralis (of Deiters)
- Nucleus vestibularis medialis (of Schwalbe)
- Nucleus vestibularis inferior (of Roller)

The vestibular system has a topographic organization:

- Afferent fibers of the macula sacculi terminate in the nucleus vestibularis inferior and nucleus vestibularis lateralis.
- Afferent fibers of the macula utriculi terminate in the medial part of the nucleus vestibularis inferior, the lateral part of the nucleus vestibularis medialis, and the nucleus vestibularis lateralis.
- Afferent fibers from the cristae ampullares of the canales semicirculares terminate in the nucleus vestibularis superior, the upper part of the nucleus vestibularis inferior, and the nucleus vestibularis lateralis.

The efferent fibers from the nucleus vestibularis lateralis pass to the tractus vestibulospinalis lateralis. This tract extends to the pars sacralis of the medulla spinalis, its axons terminating on motor neurons. Functionally, it is concerned with keeping the body upright, chiefly by increasing the tone of the extensor muscles. The vestibulocerebellar fibers from the other three nuclei act through the cerebellum to modulate muscular tone. All four nuclei vestibulares distribute ipsilateral and contralateral axons via the fasciculus longitudinalis medialis to the three motor nuclei of the nerves to the extraocular muscles (i.e., the nuclei of the nervi oculomotorius [CN III], trochlearis [CN IV], and abducens [CN VI]).



Neck

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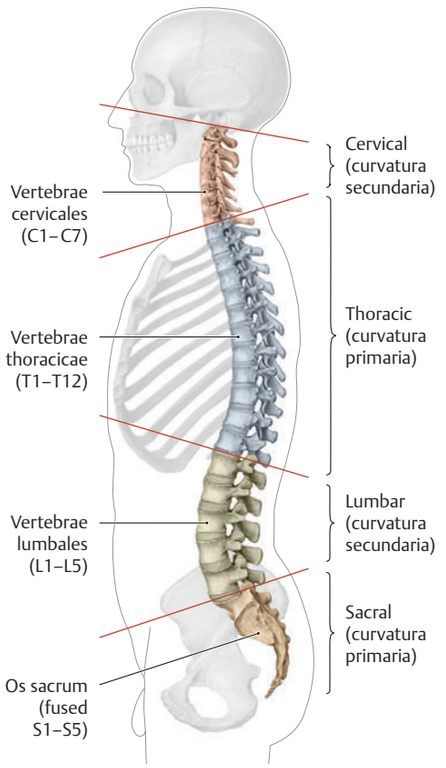


Fig. 11.1 **Spinal curvature**
Left lateral view. The columna vertebralis is divided into four regions: the cervical, thoracic, lumbar, and sacral spines. In the neonate, all regions demonstrate an anteriorly concave curvature. This single concave curvature in the neonate is referred to as the curvatura primaria of the columna vertebralis.
During development, the cervical and lumbar regions of the coulmna vertebralis develop anteriorly convex curvatures. These changes are referred to as curvaturae secundariae. The curvatura secundaria cervicalis develops as infants begin to hold up their heads. The curvaturae secundariae lumbales are the result of upright bipedal locomotion.
Kyphosis is a pathological condition where the thoracic curvatura primaria is abnormally exaggerated (hunchback, rounded back). Lordosis is a pathological condition where the curvaturae secundariae are exaggerated. Lordosis may occur in either the cervical or lumbar regions (swayback) of the columna vertebralis. Differing from the abnormal development of curvaturae primaria and secundariae, scoliosis is an abnormal lateral deviation of the columna vertebralis.

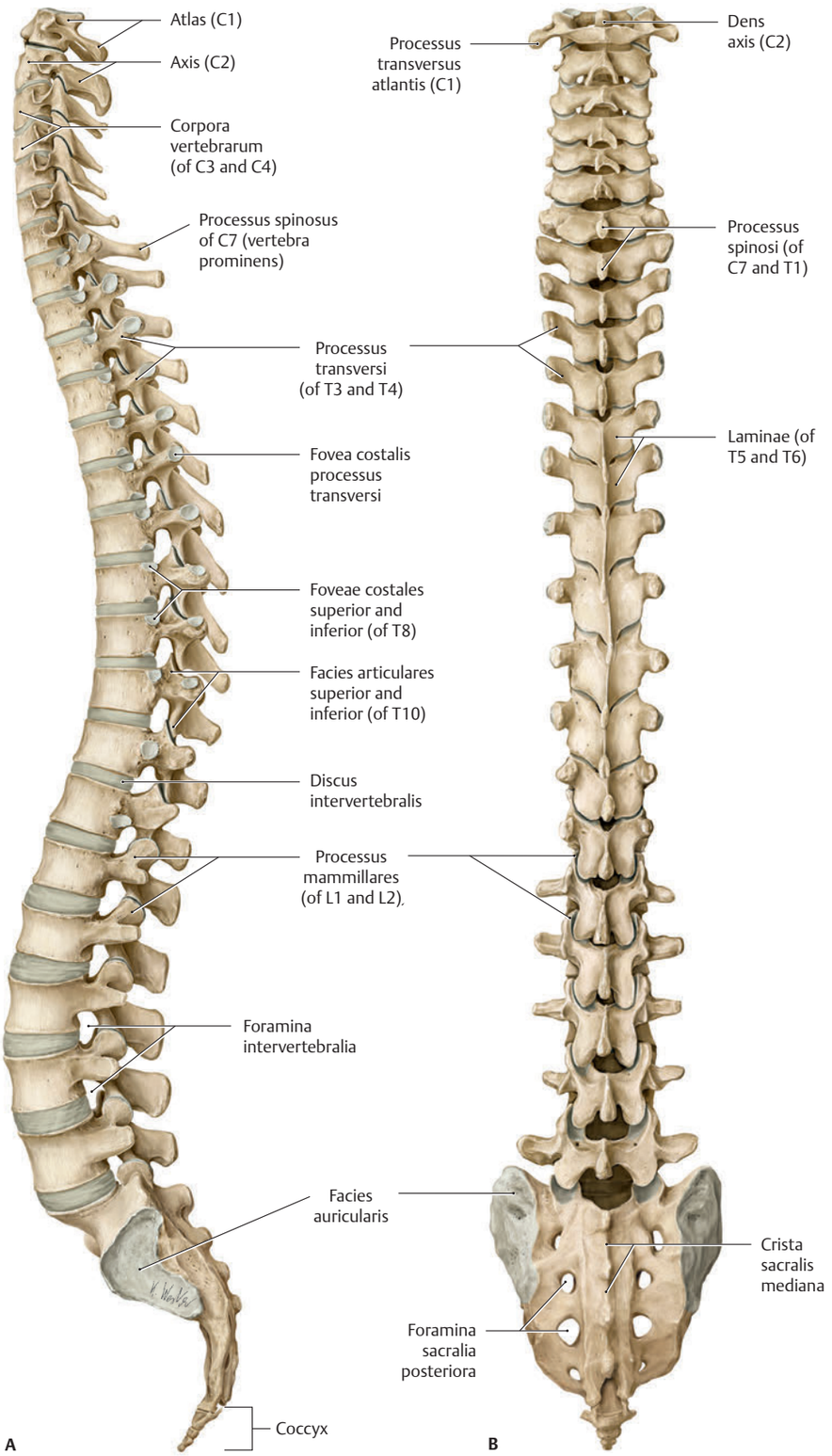
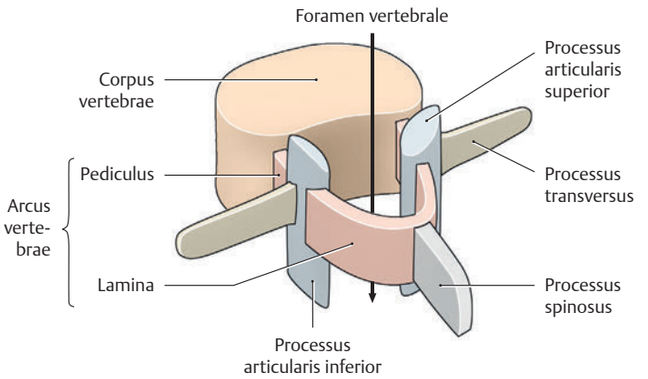
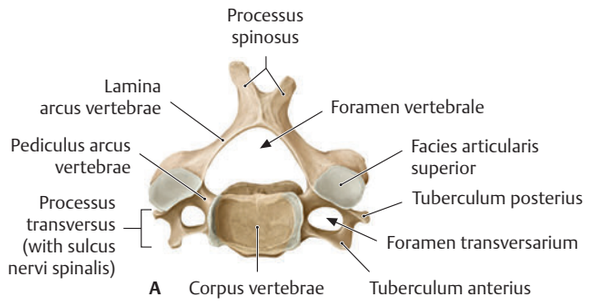
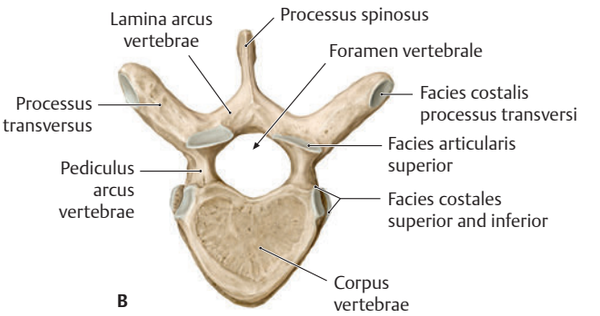


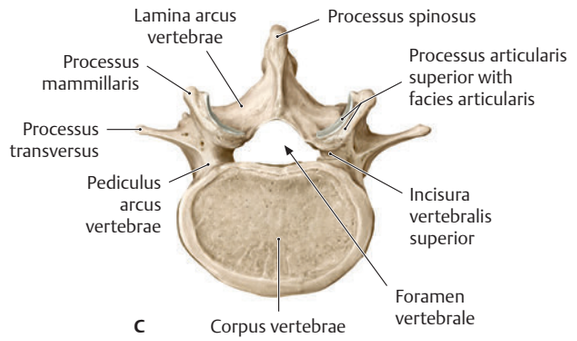
Fig. 11.2 **Columna vertebralis**
A Left lateral view. **B** Posterior view. The columna vertebralis is divided into four regions: cervical, thoracic, lumbar, and sacral. Each vertebra consists of a corpus vertebrae and arcus vertebrae. The corpora vertebrarum (with intervening disci intervertebrales) form the load-bearing component of the columna vertebralis. The arcus vertebrales enclose the canalis vertebralis, protecting the medulla spinalis.

***Fig. 11.3* Structure of vertebrae**
Schematic, left oblique posterosuperior view. Each vertebra consists of a load-bearing corpus vertebrae and an arcus vertebrae that encloses the foramen vertebrale. The arcus vertebrae is divided into the pediculus arcus vertebrae and lamina arcus vertebrae. Vertebrae have processus transversi and processus spinosi that provide sites of attachment for muscles. Vertebrae articulate at facets on the processus articulares superiores and inferiores. Vertebrae thoracicae articulate with ribs at foveae costales.









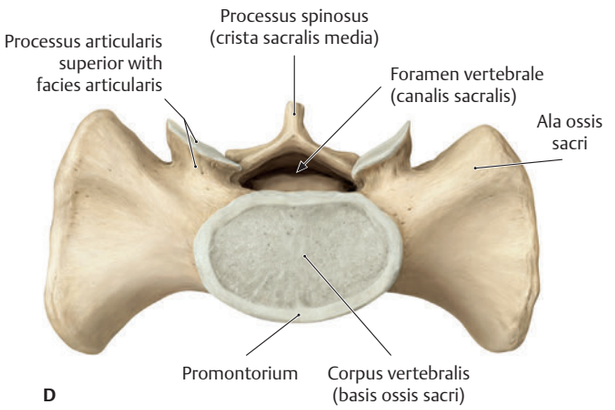


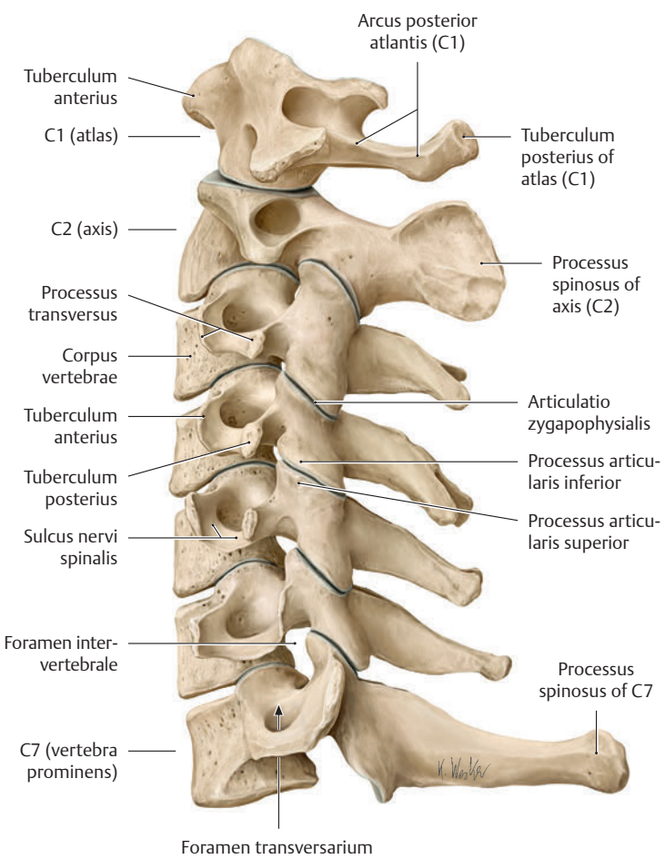
***Fig. 11.4* Typical vertebrae**
Superior view. **A** Vertebra cervicalis (C4). **B** Vertebra thoracica (T6). **C** Vertebra lumbalis (L4). **D** Os sacrum. The corpora vertebrarum increase in size cranially to caudally.

***Table 11.1* Structural elements of vertebrae**

Each vertebra consists of a corpus vertebrae and an arcus vertebrae that enclose the foramen vertebrale. The types of vertebrae can be distinguished particularly easily by examining their processus transversi. The os sacrum has structures that are analogous to the other vertebrae.

Vertebrae	Corpus	Foramen	Processus transversus	Processus spinosus
Vertebrae cervicales C3–C7	Small (kidney-shaped)	Large (triangular)	Foramina transversaria	C3–C5: short C7: long C3–C6: bifid
Vertebrae thoracicae T1–T12	Medium (heart-shaped) with costal facets	Small (circular)	Foveae costales	Long
Vertebrae lumbales L1–L5	Large (kidney-shaped)	Medium (triangular)	Processus mammillares	Short and broad
Os sacrum (fused S1–S5)	Large to small (decreases from base to apex)	Canalis sacralis (triangular)	Fused (forms ala ossis sacri)	Short (crista sacralis mediana)

Cervical Spine



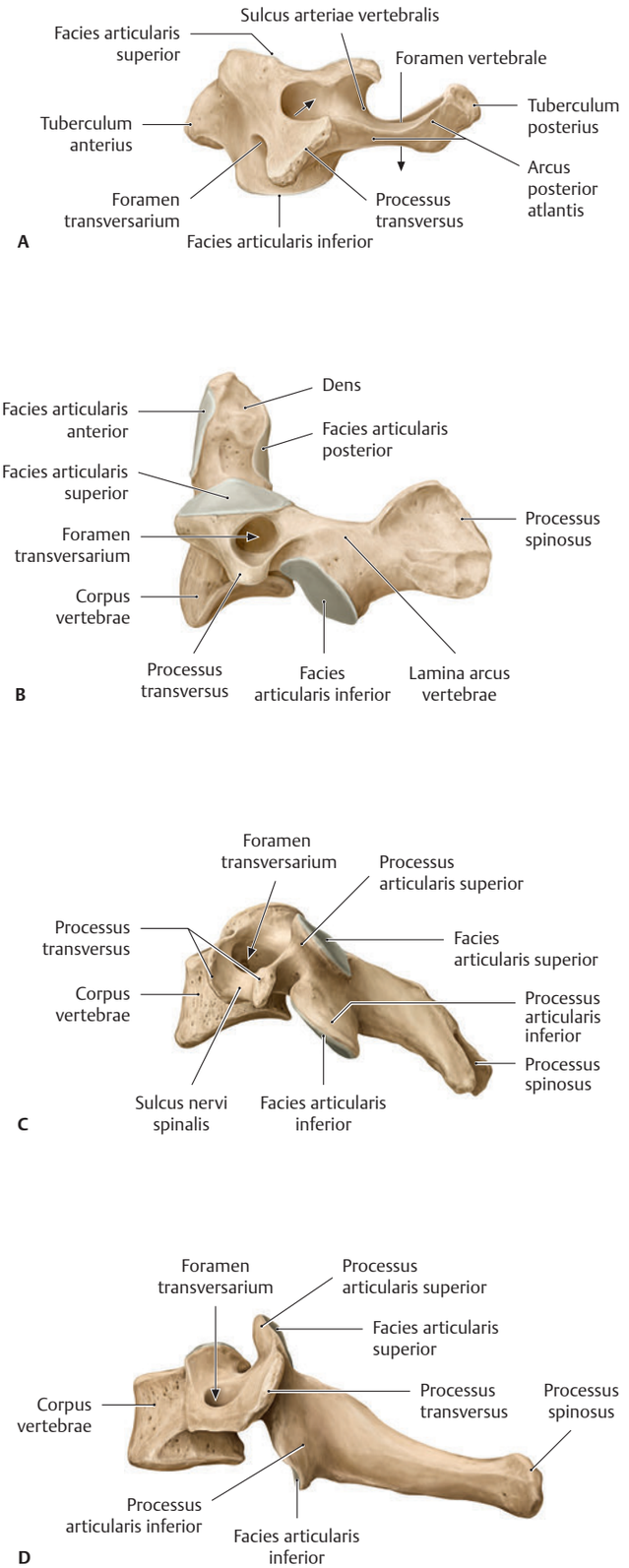
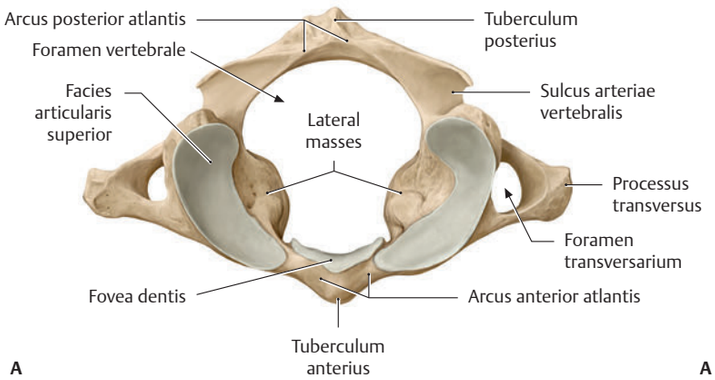


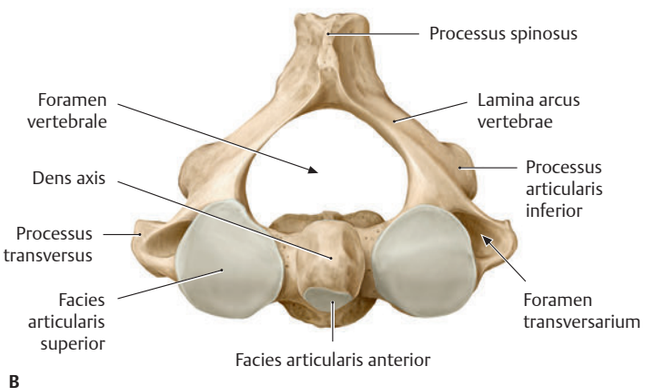
Fig. 11.5 **Cervical spine (C1–C7)**
Left lateral view. The cervical spine consists of seven vertebrae. C1 and C2 are atypical and are discussed individually.

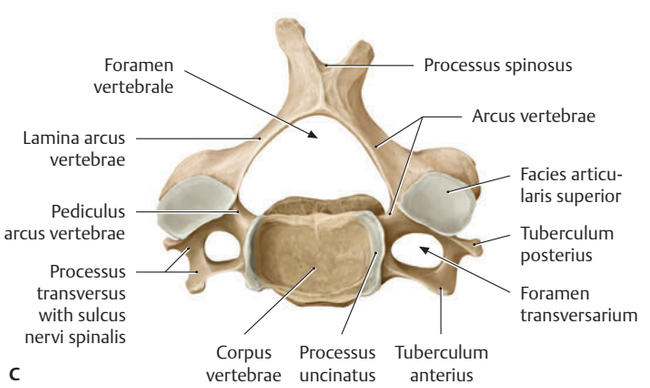
Fig. 11.6 **Left lateral view of cervical vertebrae**
A Atlas (C1). **B** Axis (C2). **C** Typical vertebra cervicalis (C4). **D** Vertebra prominens (C7).

Typical vertebrae cervicales (C3–C7): Typical vertebrae cervicales have relatively small, kidney-shaped bodies. The processus articulares superiores and inferiores are broad and flat; their facies articulares are flat and inclined at approximately 45 degrees from the horizontal. The arcus vertebrarum enclose a large, triangular foramen vertebrale. Nervi spinales emerge from the canalis vertebralis via the foramina intervertebralia formed between the pediculi of adjacent vertebrae. The processus transversi of vertebrae cervicales are furrowed to accommodate the emerging nerve (sulcus nervi spinalis). The processus transversi also consist of an anterior and a posterior portion that enclose a foramen transversarium. The foramina transversaria allow the arteria vertebralis to ascend to the base of the skull. The processus spinosi of C3–C6 are short and bifid. The processus spinosus of C7 (vertebra prominens) is longer and thicker; it is the first processus spinosus that is palpable through the skin.

Atlas (C1) and axis (C2): The atlas and axis are specialized for bearing the weight of the head and allowing it to move in all directions. The body of the axis contains a vertical prominence (dens) around which the atlas turns. The atlas does not have a corpus vertebrae: it consists of an arcus anterior atlantis and a an arcus posterior atlantis that allow the head to rotate in the horizontal plane.







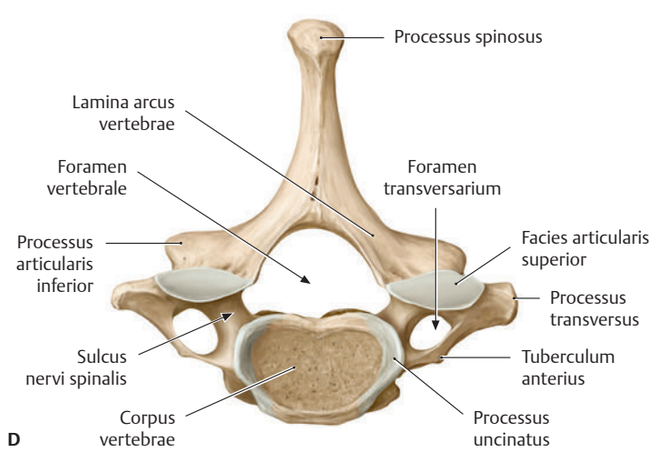
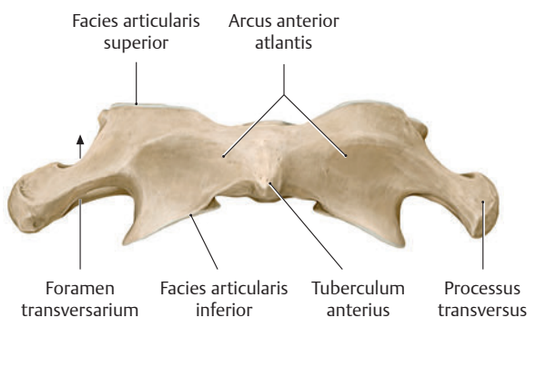
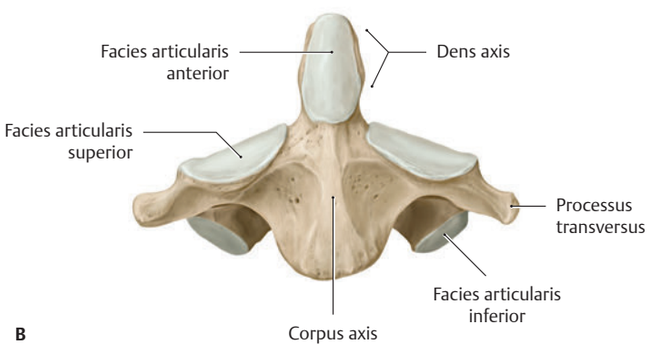
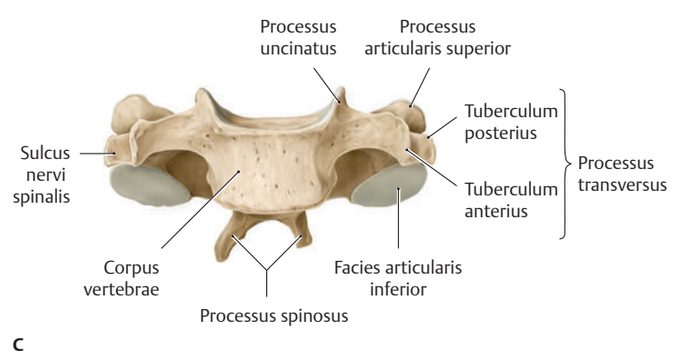


Fig. 11.7 **Superior view of vertebrae cervicales**
A Atlas (C1). **B** Axis (C2). **C** Typical vertebra cervicalis (C4). **D** Vertebra prominens (C7).







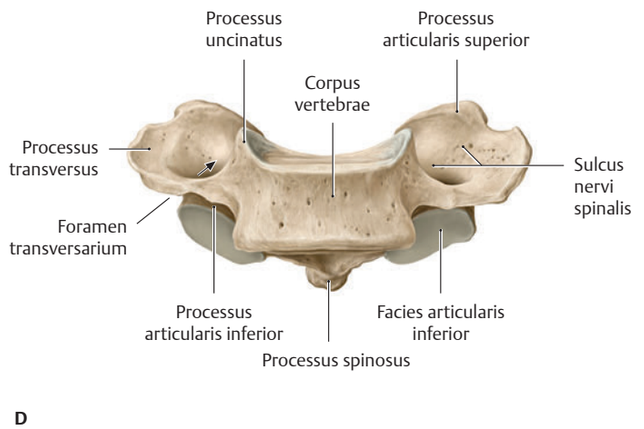


Fig. 11.8 **Anterior view of vertebrae cervicales**
A Atlas (C1). **B** Axis (C2). **C** vertebra cervicalis (C4). **D** Vertebra prominens (C7).

Joints of the Cervical Spine

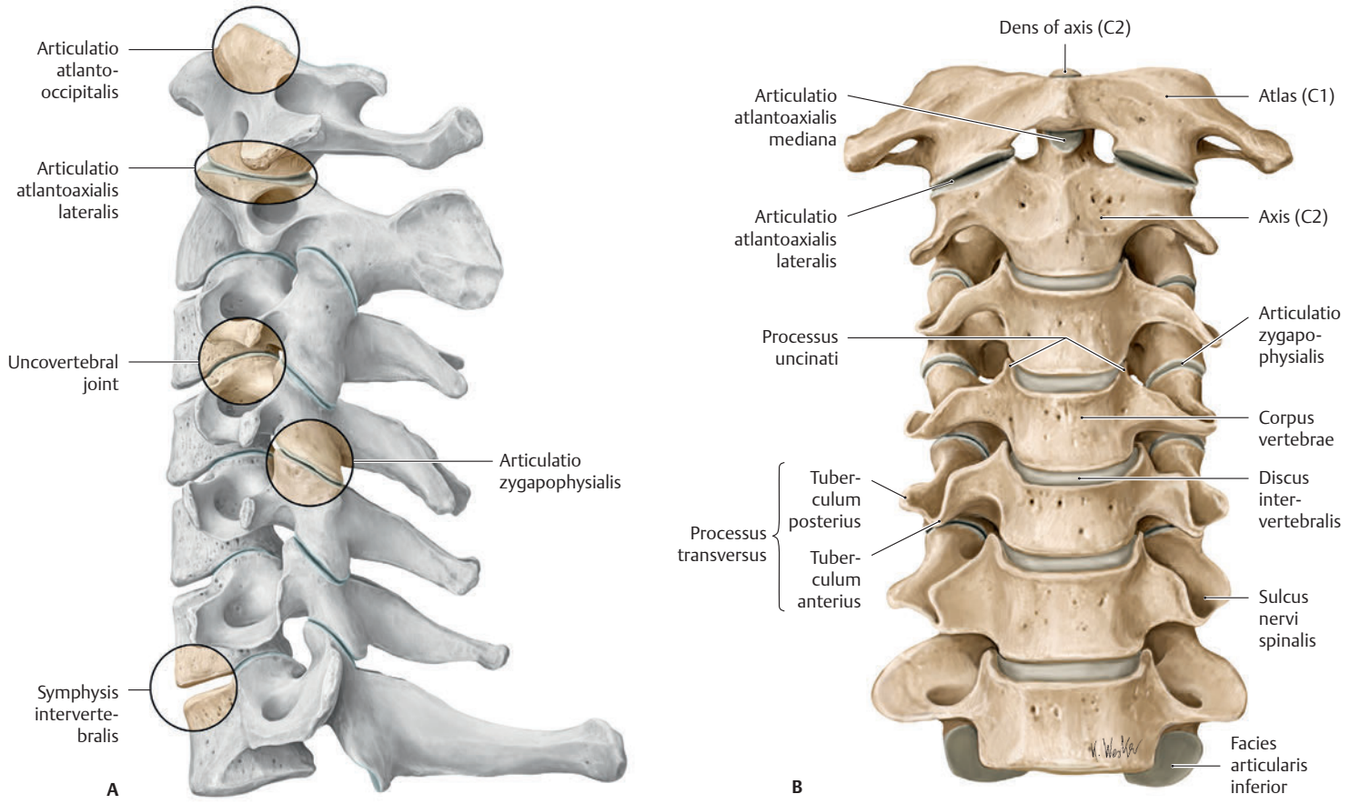


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Fig. 11.9 **Joints of the cervical spine**
A Left lateral view. **B** Anterior view. **C** Radiograph of the cervical spine, left lateral view.

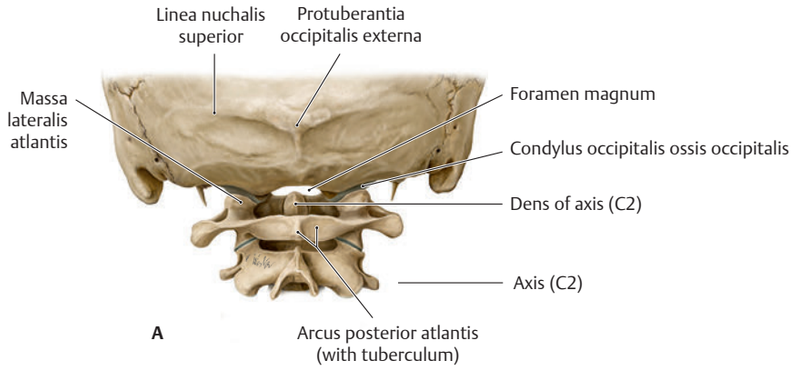
The cervical spine has five types of joints. Two joints (symphyses intervertebrales and articulationes zygapophysiales) are common to all regions of the spine, and three are specialized joints of the cervical spine.

Joints of the columna vertebralis: Adjacent vertebrae articulate at two points: corpora vertebrarum and processus articulares. The corpora of adjacent vertebrae articulate at roughly horizontal symphyses intervertebrales (via disci intervertebrales). The processus articulares of adjacent vertebrae articulate at articulationes zygapophysiales. In the cervical spine, the symphyses intervertebrales are angled slightly anteroinferiorly, and the articulationes zygapophysiales are angled posteroinferiorly (roughly 45 degrees below horizontal).

Joints of the cervical spine: There are two types of joints that are particular to the cervical spine:

1. Uncovertebral joints: Upward protrusions of the lateral margins of cervical corpora vertebrarum form processus uncinati. These processes may articulate with the inferolateral margin of the adjacent superior vertebra, forming uncovertebral joints.
2. Craniovertebral joints (articulationes atlantooccipitalis and atlantoaxiales): The atlas (C1) and axis (C2) are specialized to bear the weight of the head and facilitate movement in all directions. This is made possible by craniovertebral joints (see **Fig. 11.10**).

Laxity of the cervical spine makes it prone to hyperextension injuries, such as “whiplash,” the excessive and often violent backward movement of the head, resulting in fractures of the dens of the axis and traumatic spondylolisthesis (anterior or posterior displacement of a vertebra in relation to the one below it). Patient prognosis is largely dependent on the spinal level of the injuries.



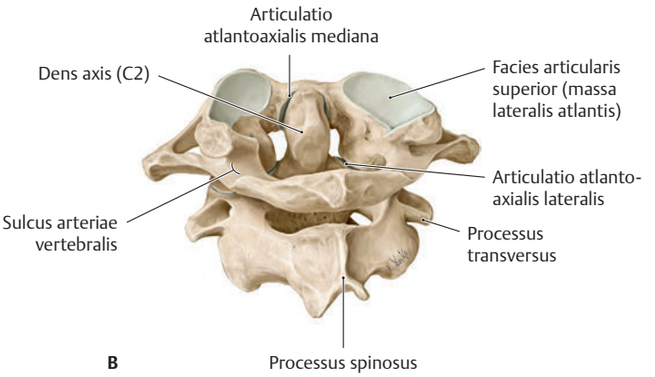
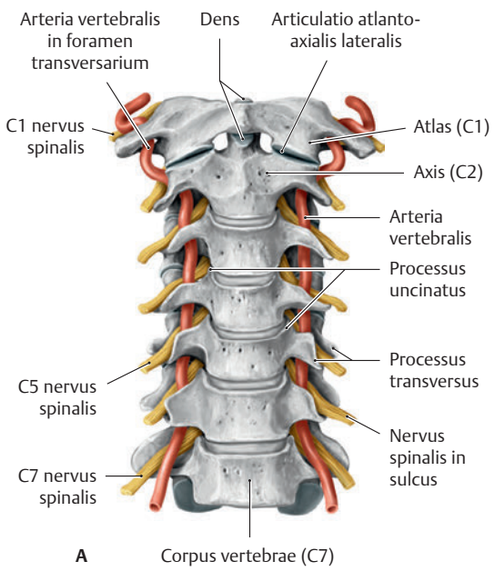


Fig. 11.10 **Craniovertebral joints**
A Posterior view. **B** Left oblique posterosuperior view.
There are five craniovertebral joints. The paired articulationes atlantooccipitales are articulations between the concave facies articulares superiores of the atlas (C1) and the convex condylus occipitalis of the os occipitale. These allow the head to rock back and forth in the sagittal plane. The articulares atlantoaxiales (two lateral and one medial) allow the atlas to rotate in the horizontal plane around the dens of the axis. The articulationes atlantoaxiales laterales are the paired articulations between the facies articulares inferiores and superiores of the atlas and axis, respectively. The articulatio atlantoaxialis mediana is the unpaired articulation between the dens of the axis and the fovea dentis of the atlas. *Note:* While only the articulationes atlantooccipitales are direct articulations between the cranium and columna vertebralis, the articulationes atlantoaxiales are generally classified as craniovertebral joints as well.



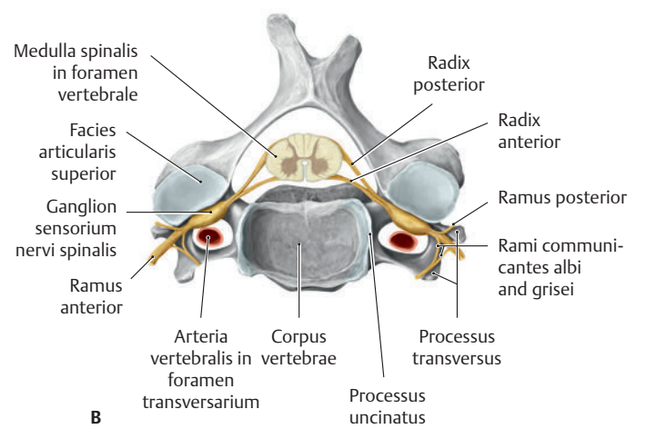


Fig. 11.11 **Neurovasculature of the cervical spine**
A Anterior view. **B** Superior view.
The processus transversi of the vertebrae cervicales are extremely important in communicating neurovascular structures. Nervi spinales arise from the medulla spinosa in the canalis vertebralis. They exit via the foramina intervertebralia formed by the pediculi of adjacent vertebrae. The processus transversi of vertebrae cervicales contain grooves (sulci) through which the nervi spinales pass. The processus transversi also contain foramina transversaria that allow the arteria vertebralis to ascend from the arteria subclavia and enter the skull via the foramen magnum. Injury to the cervical spine can compress the neurovascular structures as they emerge and ascend from the columna vertebralis.

Ligaments of the Columna Vertebralis

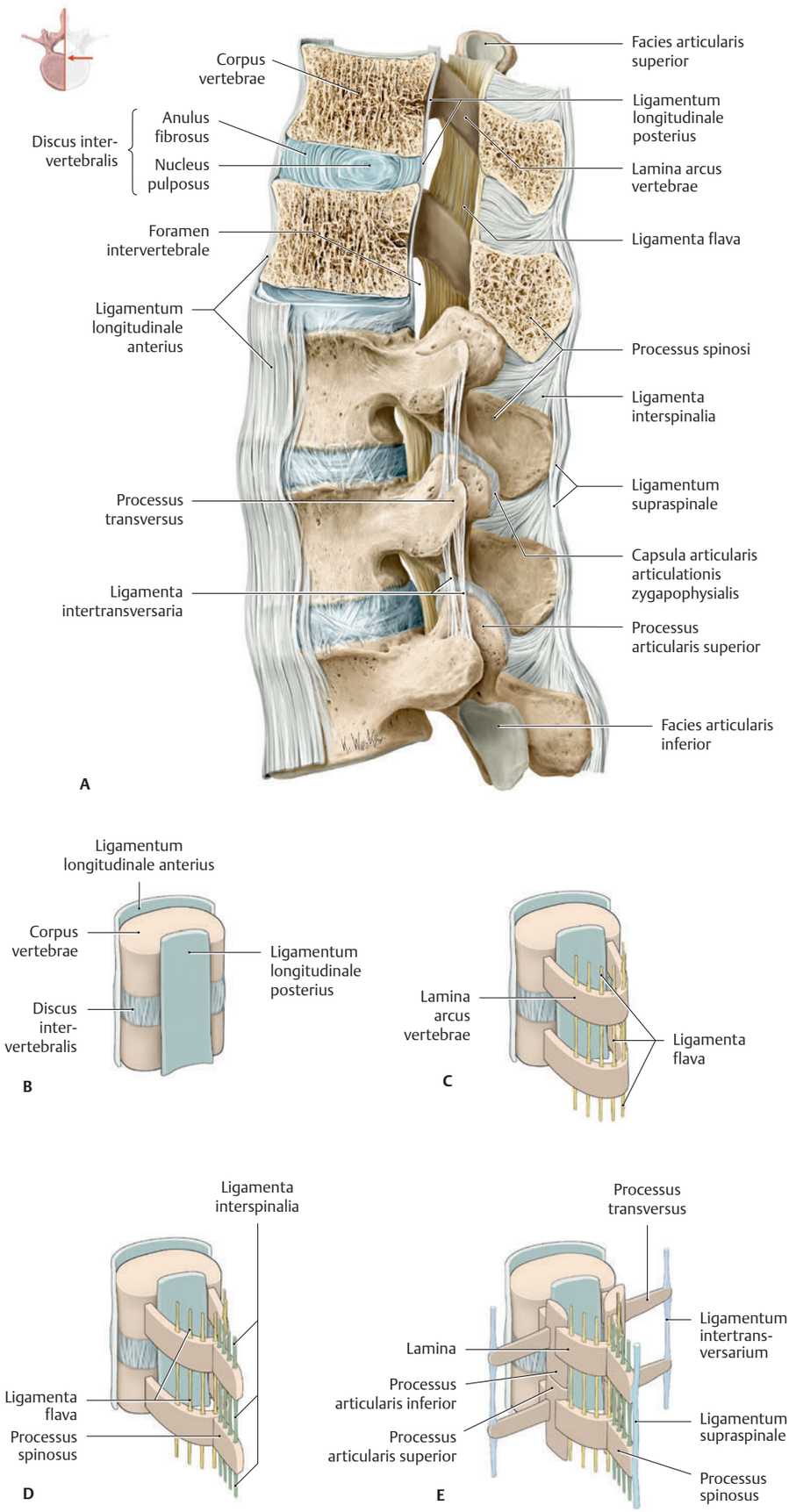
***Fig. 11.12* Ligaments of the columna vertebralis**

The ligaments of the columna vertebralis bind the vertebrae to one another and enable the spine to withstand high mechanical loads and shearing stresses. The ligaments are divided into ligaments of the corpora vertebrarum and arcus vertebrarum (**Table 11.2**).

A Ligaments of the columna vertebralis. Left lateral view of T11–L3 with T11 and T12 sectioned midsagittally.
B Ligaments of the corpus vertebrae (ligamenta longitudinalia anterius and posterius, and discus intervertebralis), schematic.
C Ligamenta flava, schematic.
D Ligamenta interspinalia and ligamenta flava, schematic.
E Complete ligaments of the columna vertebralis, schematic.

***Table 11.2* Ligaments of the columna vertebralis**

Ligamenta corporum vertebrarum
Ligamentum longitudinale anterius (along anterior surface of corpora vertebrarum)
Ligamentum longitudinale posterius (along posterior surface of corpora vertebrarum, i.e., anterior surface of canalis vertebralis)
Discus intervertebralis (between adjacent corpora vertebrarum; the anulus fibrosus limits rotation, and the nucleus pulposus absorbs compressive forces)
Ligamenta arcuum vertebrarum
Ligamenta flava (between laminae)
Ligamenta interspinalia (between processus spinosi)
Ligamenta supraspinalia (along posterior border of processus spinosi; in the cervical spine, the ligamentum supraspinale is broadened into the ligamentum nuchae)
Ligamenta intertransversaria (between processus transversi)
Capsulae articulares articulationum zygapophysialium (enclose the articulation between the facets of the processus articulares superiores and inferiores of adjacent vertebrae)



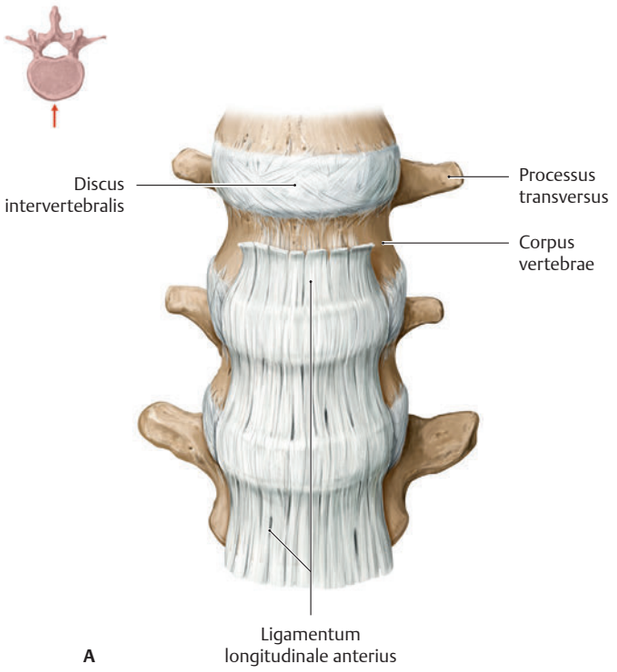


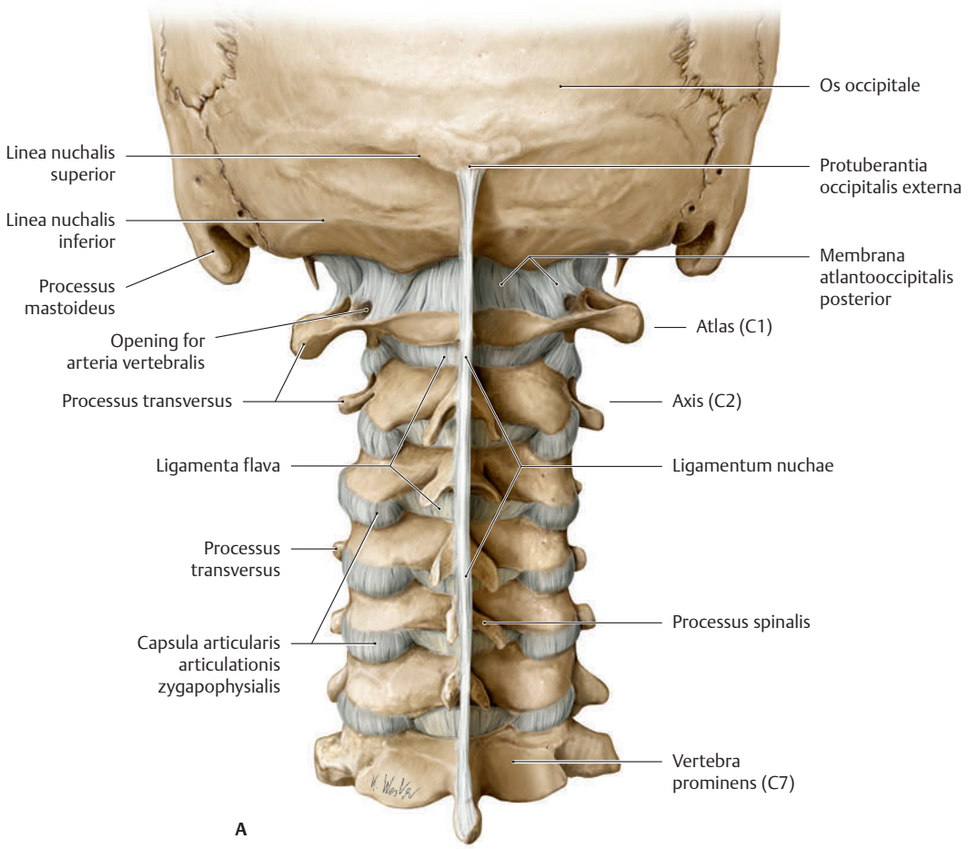
Fig. 11.13 **Individual ligaments of the columna vertebralis**
The ligamenta longitudinalia anterius and posterius and ligamenta flava maintain the normal curvature of the spine.

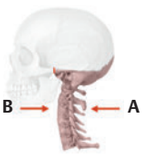
A Ligamentum longitudinale anterius. Anterior view. The ligamentum longitudinale anterius runs broadly on the anterior side of the corpora vertebrarum from the skull base to the os sacrum. Its deep collagenous fibers bind adjacent corpora vertebrarum together (they are firmly attached to corpora vertebrarum and loosely attached to disci intervertebrales). Its superficial fibers span multiple vertebrae.

B Ligamentum longitudinale posterius. Posterior view with canalis vertebralis windowed (arcus vertebrarum removed). The thinner ligamentum longitudinale posterius descends from the clivus along the posterior surface of the corpora vertebrarum, passing into the canalis sacralis. The ligament broadens at the level of the discus intervertebralis (to which it is attached by tapered lateral extensions). It narrows again while passing the corpus vertebrae (to which it is attached at the superior and inferior margins).

C Ligamenta flava and ligamenta intertransversaria. Anterior view with canalis vertebralis windowed (corpora vertebrarum removed). The ligamentum flavum is a thick, powerful ligament that connects adjacent laminae and reinforces the wall of the canalis vertebralis posterior to the foramina intervertebralia. The ligament consists mainly of elastic fibers that produce the characteristic yellow color. When the columna vertebralis is erect, the ligamenta flava are tensed, stabilizing the spine in the sagittal plane. The ligamenta flava also limit forward flexion of the spine. *Note:* The tips of the processus transversi are connected by ligamenta intertransversaria that limit the rocking movements of vertebrae upon one another.

Ligaments of the Cervical Spine





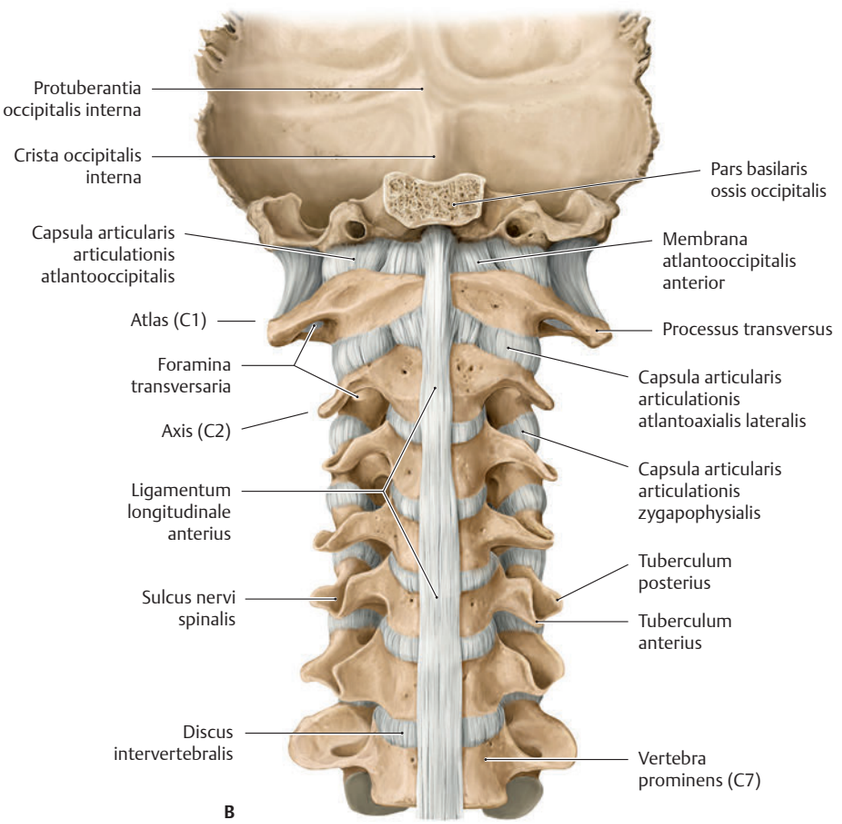
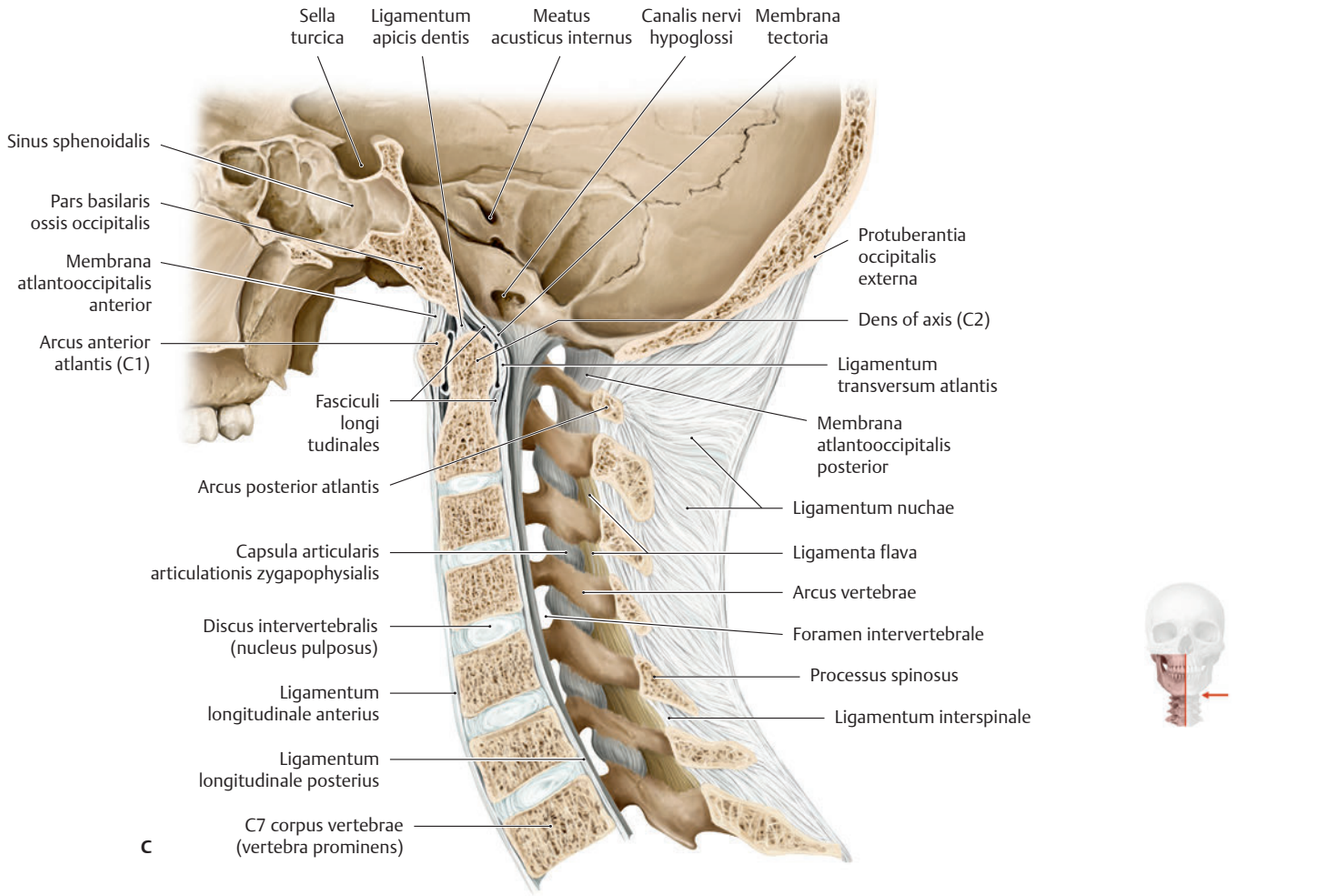


Fig. 11.14 **Ligaments of the cervical spine**

A Posterior view.

B Anterior view after removal of the anterior skull base.

C Midsagittal section, left lateral view. The ligamentum nuchae is the broadened, sagittally oriented part of the ligamentum supraspinale that extends from the vertebra prominens (C7) to the protuberantia occipitalis externa.



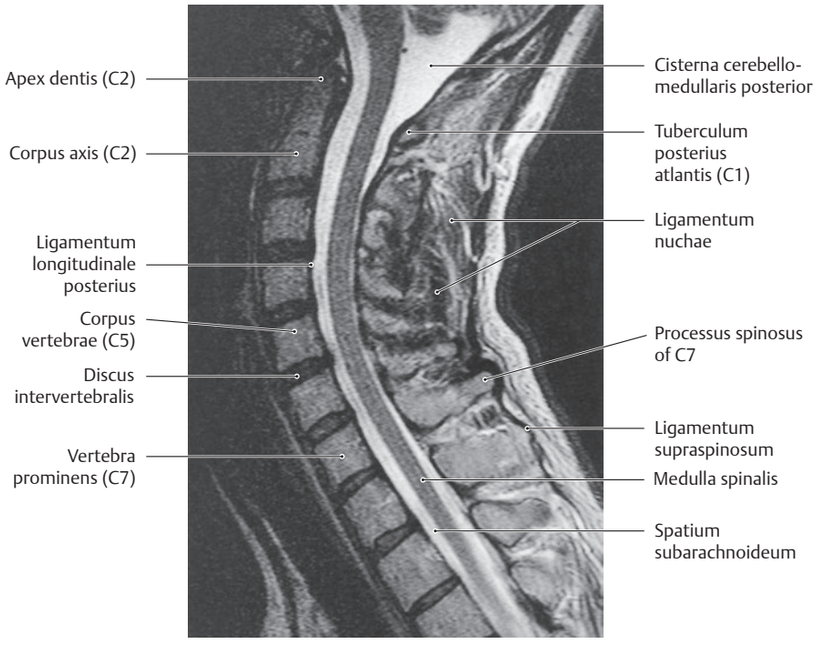


Fig. 11.15 **Magnetic resonance image of the cervical spine**
Midsagittal section, left lateral view, T2-weighted TSE sequence.
(From Vahlensieck M, Reiser M. MRT des Bewegungsapparates. 2nd ed. Stuttgart: Thieme; 2001.)

Ligaments of the Craniovertebral Joints

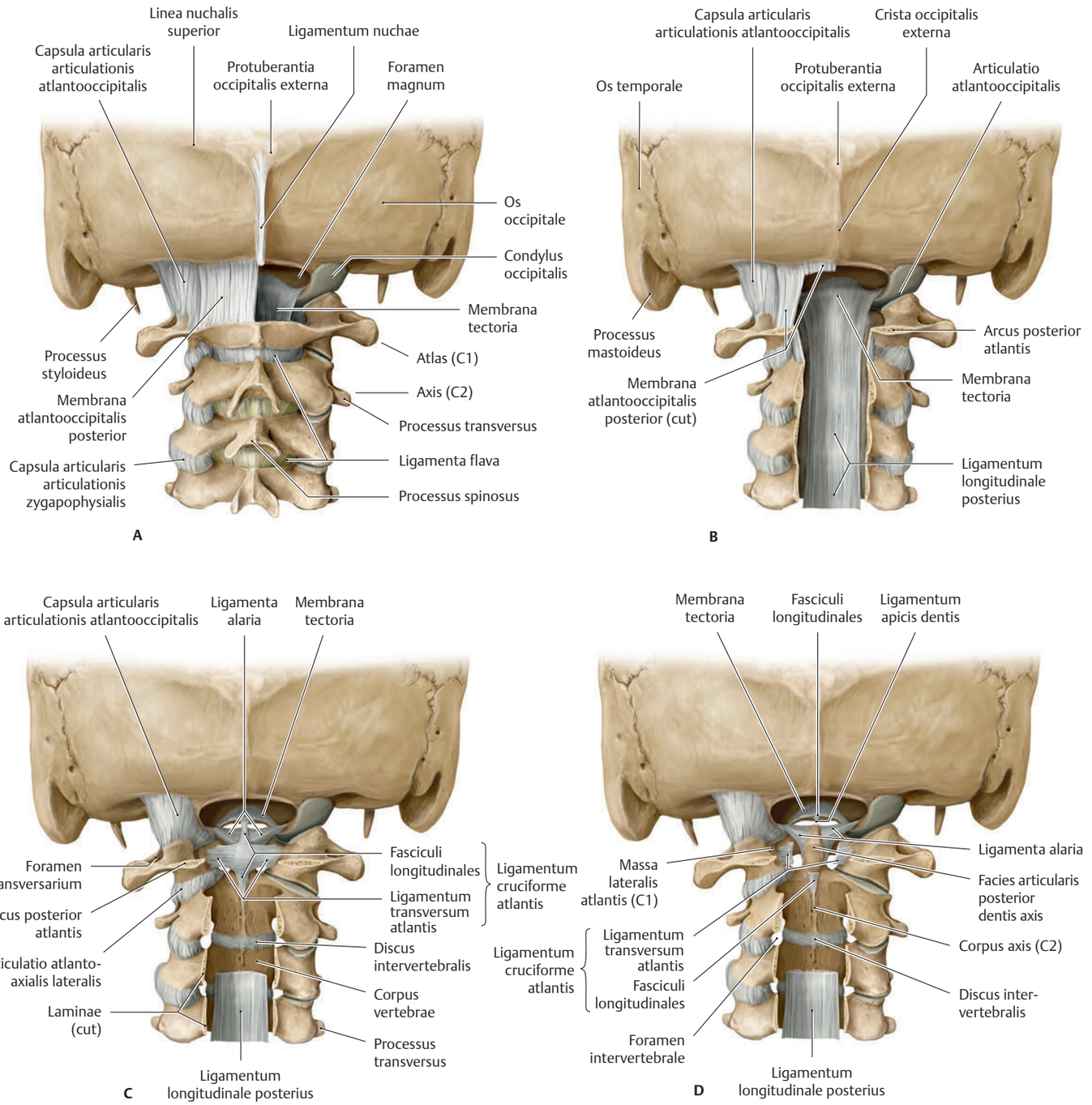


Fig. 11.16 **Ligaments of the craniovertebral joints and cervical spine**

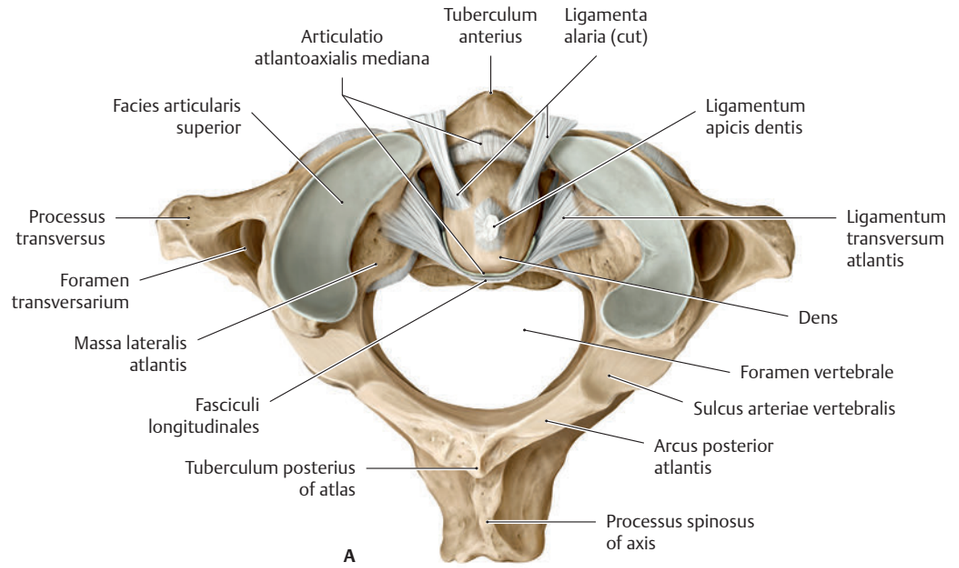
Skull and upper cervical spine, posterior view.

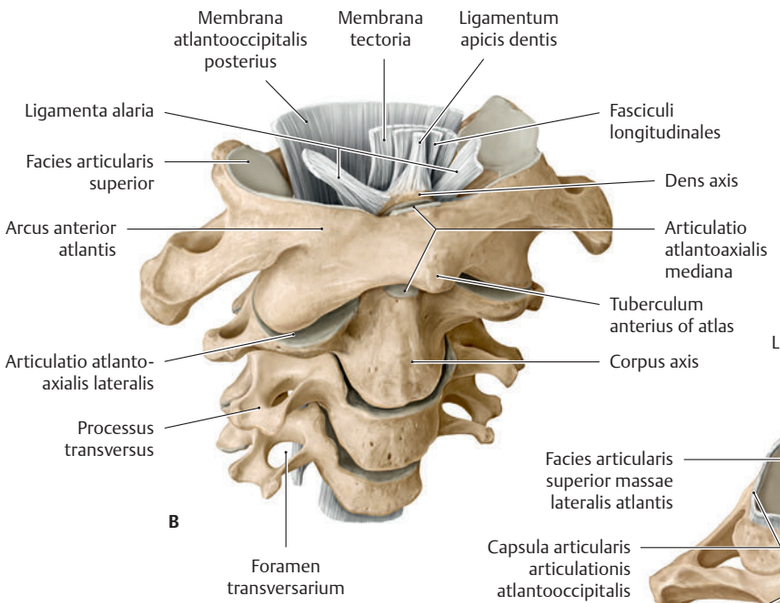
A The membrana atlantooccipitalis posterior stretches from the arcus posterior atlantis to the posterior rim of the foramen magnum. This membrane has been removed on the right side.

B With the canalis vertebralis opened and the medulla spinalis removed, the membrana tectoria, a broadened expansion of the ligamentum longitudinale posterius, is seen to form the anterior boundary of the canalis vertebralis at the level of the craniovertebral joints.

C With the membrana tectoria removed, the ligamentum cruciforme atlantis can be seen. The ligamentum transversum atlantis forms the thick horizontal bar of the cross, and the fasciculi longitudinales form the thinner vertical bar.

D The ligamentum transversum atlantis and fasciculi longitudinales have been partially removed to demonstrate the paired ligamenta alaria, which extend from the lateral surfaces of the dens axis to the corresponding inner surfaces of the condyli occipitales, and the unpaired ligamentum apicis dentis, which passes from the apex dentis to the anterior rim of the foramen magnum.





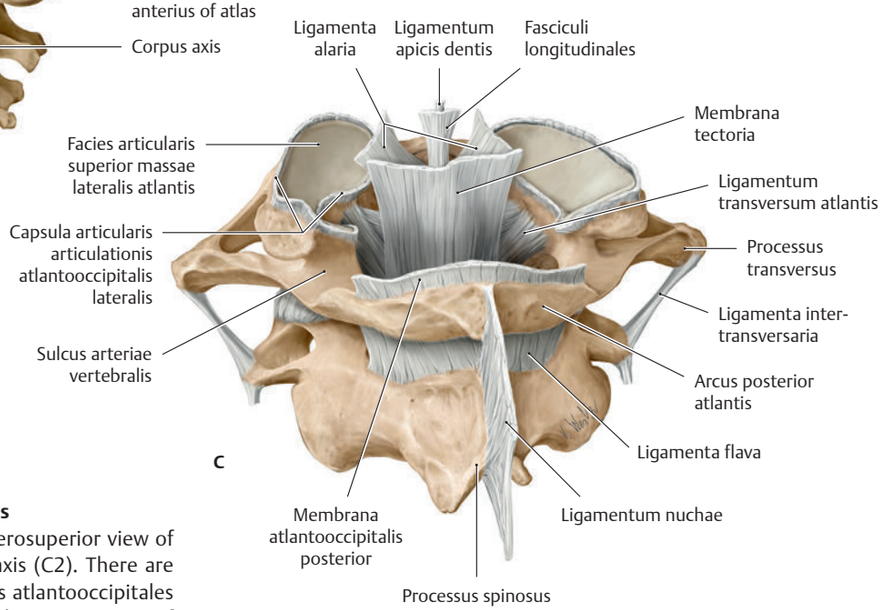


Fig. 11.17 **Ligaments of the craniovertebral joints**
A Superior view of atlas (C1) and axis (C2). **B** Anterosuperior view of C1–C4. **C** Posterosuperior view of atlas (C1) and axis (C2). There are five craniovertebral joints. The paired articulationes atlantooccipitales are articulations between the concave facies articulares superiores of the atlas and the convex condyli occipitales of the os occipitale. The joints are stabilized by the capsula articularis articulationis atlantooccipitalis and the membrana atlantooccipitalis posterior (the equivalent of the ligamenta flava). The paired articulationes atlantoaxiales laterales and unpaired articulatio atlantoaxialis mediana allow the atlas to rotate in the horizontal plane around the dens of the axis. They are stabilized by the ligamenta alaria, the ligamentum apicis dentis, and the ligamentum cruciforme atlantis (ligamentum transversum and fasciculi longitudinales).

Muscles of the Neck: Overview

Fig. 11.18 **Musculus sternocleidomastoideus and musculus trapezius**
A Musculus sternocleidomastoideus, right lateral view.
B Musculus trapezius, posterior view.

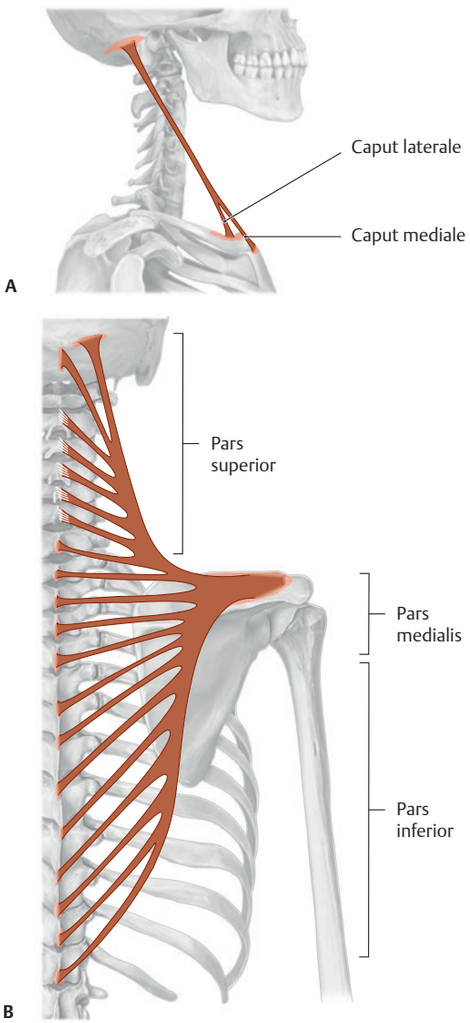


Fig. 11.19 **Superficial neck muscles**
A Left lateral view. **B** Anterior view of musculi sternocleidomastoideus and trapezius. Unlike the rest of the neck muscles, the superficial neck muscles are located superficial to the lamina prevertebralis of the fascia cervicalis and are innervated by the rami anteriores of the nervi spinales.

Platysma: The platysma, like the muscles of facial expression, is not enveloped in its own fascial sheath, but is instead directly associated with (and in parts inserted into) the skin. (*Note:* It is innervated by the same nerve as the muscles of facial expression, the facial nerve.) The platysma is highly variable in size — its fibers may reach from the lower face to the upper thorax.

***Table 11.3* Muscles of the neck**

The muscles of the neck lie at the intersection of the skull, columna vertebralis, and upper limb. They can therefore be classified in multiple ways based on location and function. In the pages that follow, the neck muscles are grouped as follows:

Superficial neck muscles

Muscles that lie superficial to the lamina prevertebralis of the fascia cervicalis and are innervated by the rami anteriores of nervi spinales

Posterior neck muscles (intrinsic back muscles)

Muscles that insert on the cervical spine and are innervated by the rami posteriores of nervi spinales
- Musculi dorsi proprii (including nuchal muscles)
  - Short nuchal/craniovertebral muscles

Anterior neck muscles

Muscles that insert on the anterior cervical spine and are innervated by the rami anteriores of nervi spinales
- Anterior vertebral (prevertebral) muscles
- Lateral vertebral muscles (scalenes)

Muscles that do not insert on the cervical spine
- Musculi suprahyoidei
- Musculi infrahyoidei

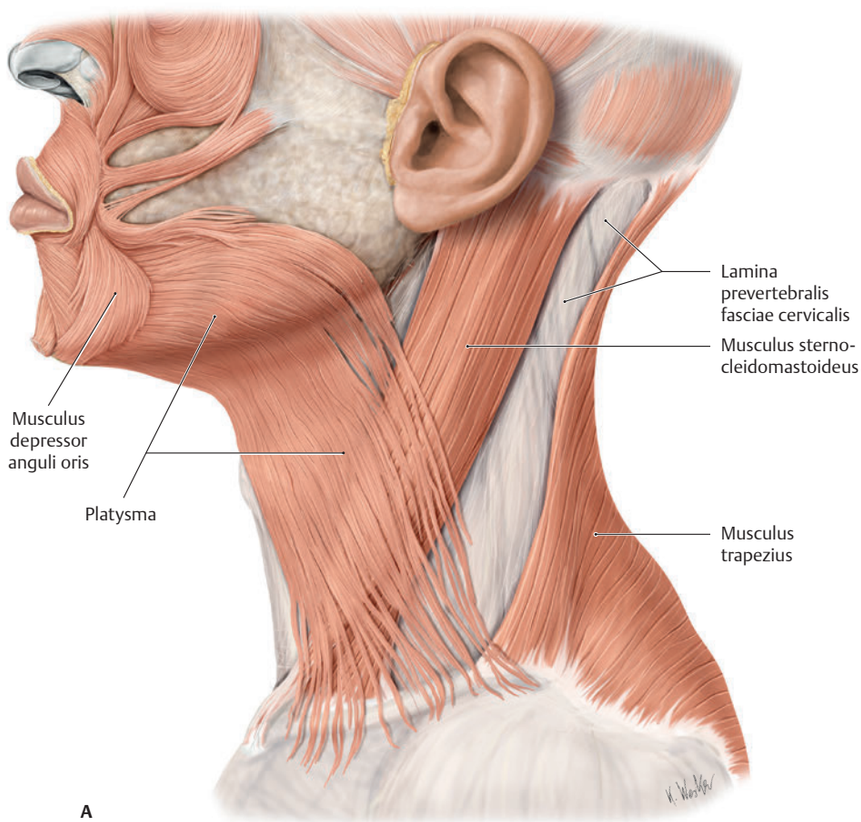


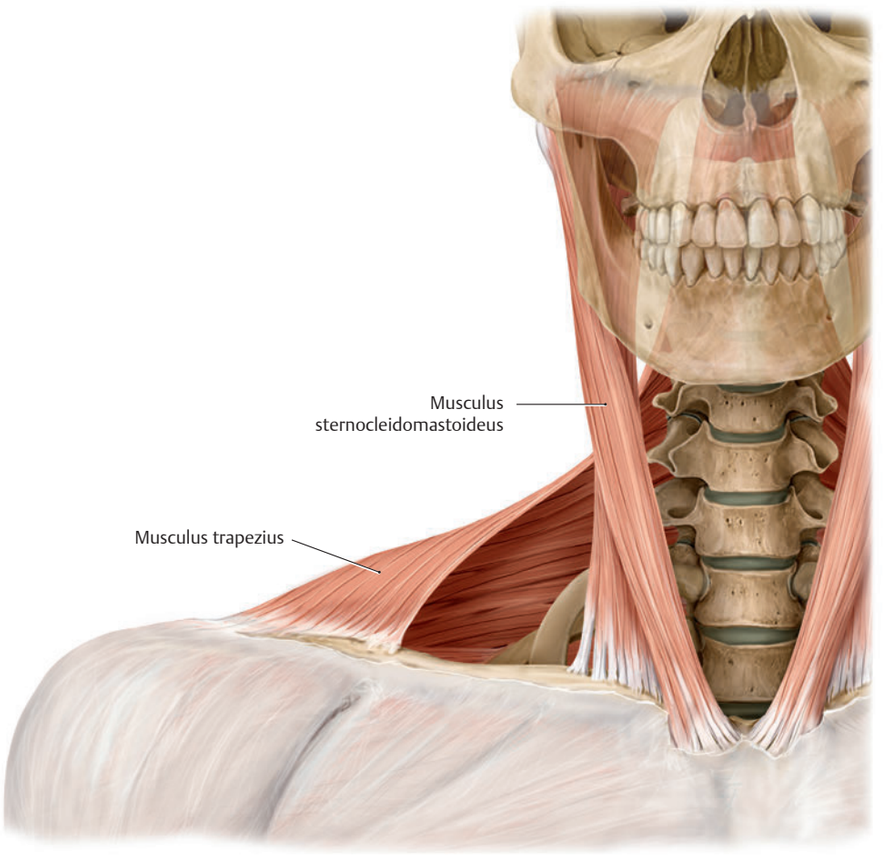
Table 11.4 **Superficial neck muscles**

Muscle	Origin	Insertion	Innervation	Action
Platysma	Mandibula (inferior border); skin of lower face and angulus oris	Skin over lower neck and superior and lateral thorax	Nervus facialis (CN VII), ramus cervicalis	Depresses and wrinkles skin of lower face and mouth; tenses skin of neck; aids forced depression of mandibula
Musculus sternocleidomastoideus	Os occipitale (linea nuchalis superior); os temporale (processus mastoideus)	Caput mediale: sternum (manubrium sterni) Caput laterale: clavicula (medial ⅓)	Nervus accessorius (CN IX), radix spinalis	*Unilateral:* Moves chin up and out (tilts head to same side and rotates head to opposite side) *Bilateral:* Extends head; aids in respiration when head is fixed
Musculus trapezius, pars descendens*	Os occipitale; C1–C7 (processus spinosi)	Clavicula (lateral ⅓)		Draws scapula obliquely upward; rotates cavitas glenoidalis inferiorly
Musculus rhomboideus minor (see **Fig. 11.20**)	Ligamentum nuchae (inferior part), C7–T1 (processus spinosi)	Margo medialis of the scapula, superior to the intersection with the spina scapulae	C4–C5 rami anteriores (C5 fibers are from the nervus dorsalis scapulae)	Scapular movements (e.g., retraction and rotation)
Musculus levator scapulae (see **Fig. 11.20**)	C1–C4 (tubercula posteriora of processus transversi)	Scapula (medial to angulus superior)	C3–C5 rami anteriores (C5 fibers are from the nervus dorsalis scapulae)	Scapular movements (e.g., elevation, retraction, and rotation)
Musculus serratus posterior superior (see **Fig. 11.22**)	Ligamentum nuchae (inferior part), C7–T3 (processus spinosi)	Ribs 2–5	Rami anteriores of thoracic spinal nn. (nervi intercostales)	Postulated to be an accessory muscle of respiration; assists in elevating ribs

*The partes transversa and ascendens are not described here.

Musculi sternocleidomastoideus and trapezius: The musculus trapezius lies between the laminae superficialis and prevertebralis of the fascia cervicalis. The lamina superficialis splits to enclose the musculus sternocleidomastoideus and the musculus trapezius.

Congenital torticollis (wryneck) is a condition in which shortening of the musculus sternocleidomastoideus causes the head to tilt to one side with the chin pointing upward to the opposite side. This shortening is thought to be the result of trauma at birth causing bleeding and swelling within the muscle and subsequent scar tissue which renders the muscle unable to lengthen in the growing neck. It is often associated with hip dysplasia. Symptoms that appear in infancy include abnormal posturing of the head and chin, limited range of motion in the neck, and one side of the face and head may flatten as the child sleeps on one side only.



B

Muscles of the Neck & Back (I)

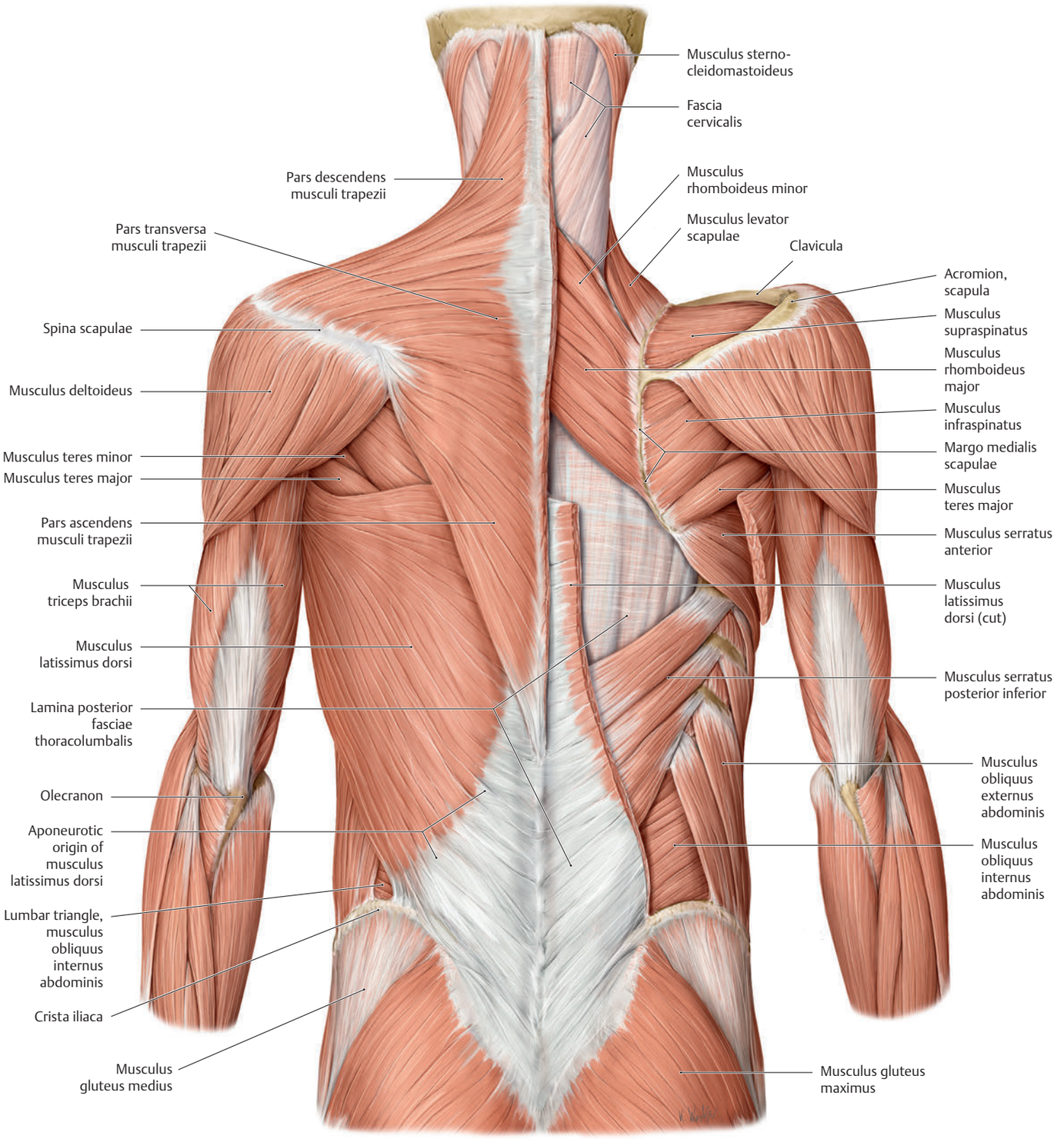


Fig. 11.20 **Muscles of the neck and back**
Posterior view with musculi trapezius and latissimus dorsi cut on right side. The extrinsic back muscles lie superficial to the fascia thoracolumbalis and lamina prevertebralis fasciae cervicalis. They are muscles of the upper limb (derived from the limb buds) that have migrated to the back. The intrinsic back muscles (musculi dorsi proprii) lie between the fascia thoracolumbalis and lamina prevertebralis fasciae cervicalis. They are derived from epaxial muscle. Because of their different embryonic origins, the musculi dorsi proprii are innervated by the rami posteriores of the nervi spinales, and the extrinsic back muscles are innervated by the rami anteriores. Note: The musculi trapezius and sternocleidomastoideus are innervated by the nervus accessorius (CN XI).

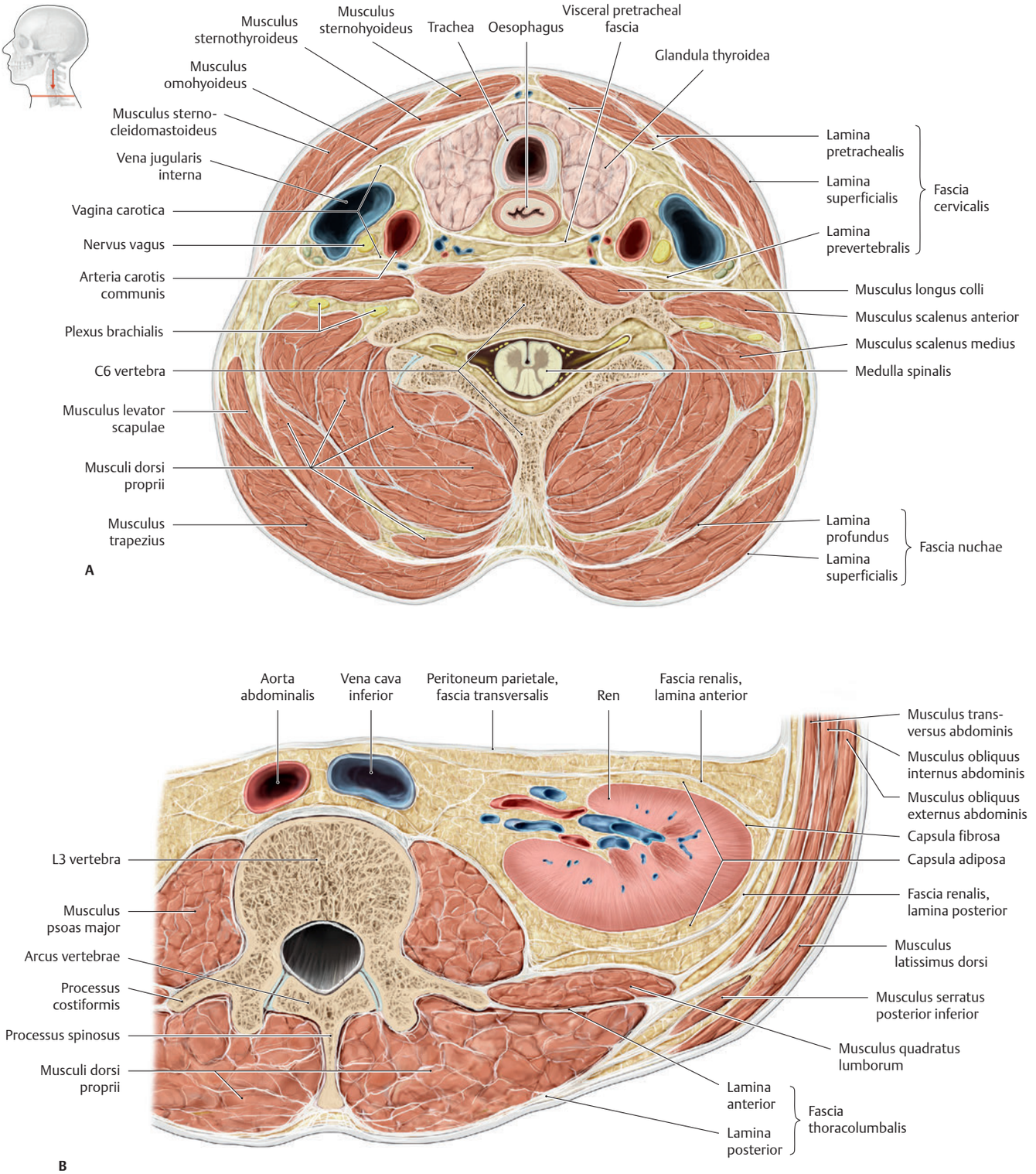


Fig. 11.21 **Fascial planes**
Transverse sections, superior view.
A Neck at the level of the C6 vertebra.
B Posterior trunk wall at the level of the L3 vertebra (with cauda equina removed from canalis vertebralis).

The muscles of the neck and back are separated by layers of deep fascia (see p. 300). The outermost layer, the lamina superficialis of the fascia cervicalis, encloses all muscles with the exception of the platysma (this is located in the superficial fascia, not to be confused with the lamina superficialis of the fascia cervicalis). The fascia cervicalis, located in the anterior neck, is continuous posteriorly with the fascia nuchae in the posterior neck. The lamina superficialis of the fascia nuchae is continuous inferiorly with the lamina posterior of the fascia thoracolumbalis. The intrinsic muscles of the neck and back lie within the lamina profundus of the fascia nuchae, which is continuous with the lamina prevertebralis fasciae cervicalis (anteriorly) and fascia thoracolumbalis (inferiorly). The muscles and structures of the anterior neck are enclosed in individual fascial sheaths (i.e., the visceral pretracheal fascia, muscular pretracheal fascia, and vagina carotica).

Muscles of the Neck & Back (II)

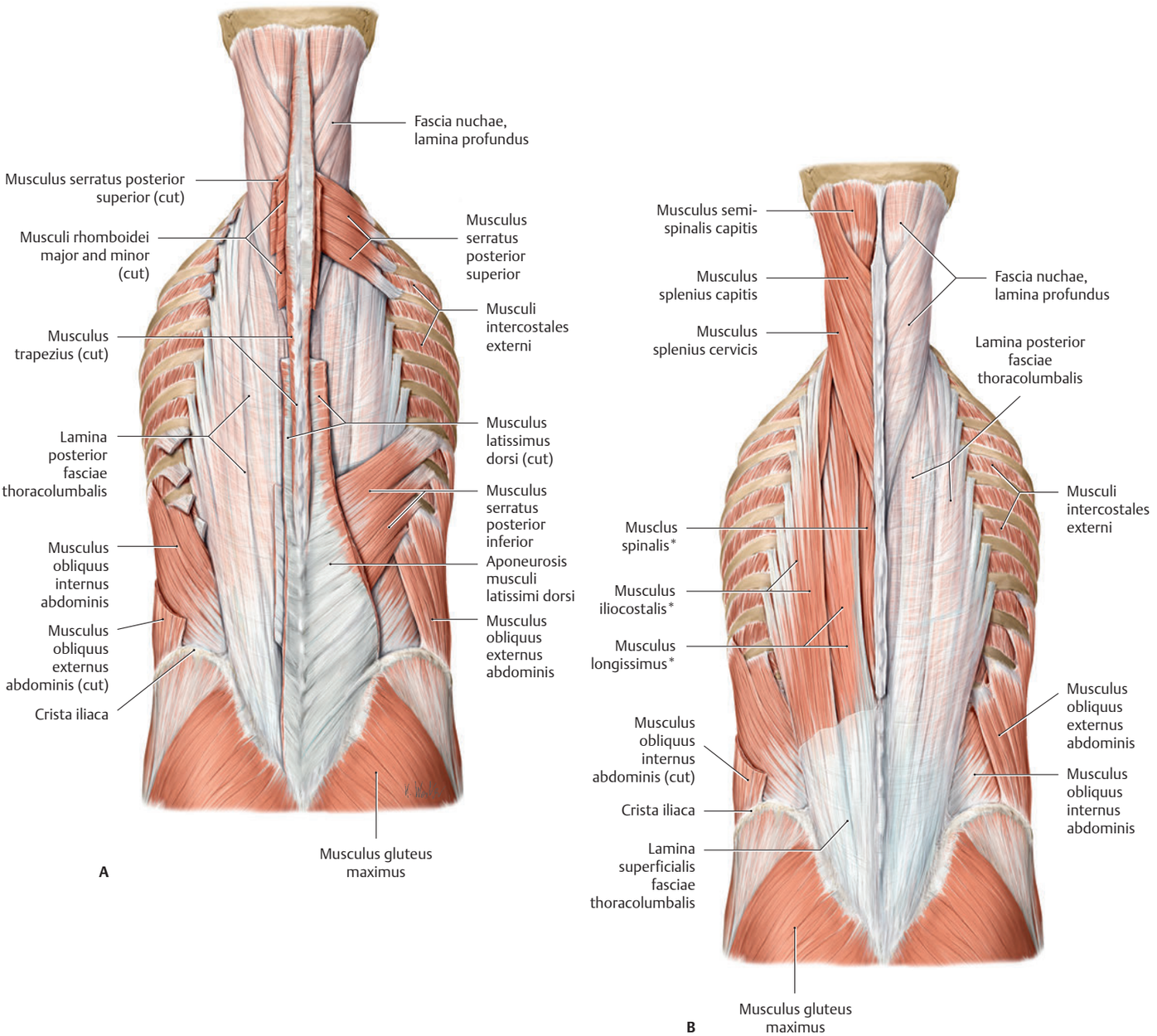


Fig. 11.22 **Extrinsic and intrinsic back muscles**
Posterior view. These dissections demonstrate the distinction between the musculi dorsi proprii and the surrounding extrinsic back muscles and trunk muscles. The musculi dorsi proprii lie within the lamina profundus of fascia nuchae, which is continuous inferiorly with the lamina posterior of the fascia thoracolumbalis. They are derived from epaxial muscles and therefore innervated by the rami posteriores of nervi spinales (see p. 304). The muscles of the trunk are derived from hypaxial muscle and therefore innervated by the rami anteriores of nervi spinales. The visible trunk muscles are the abdominal muscles (musculi obliquus internus abdominis and externus abdominis) and the thoracic muscles (musculi intercostales externi).

A *Removed:* Extrinsic back muscles (with the exception of the musculus serratus posterior and the aponeurotic origin of the musculus latissimus dorsi on the right side).
B *Removed:* All extrinsic back muscles and portions of the fascial covering (deep fascia nuchae and lamina posterior of the fascia thoracolumbalis).

*The musculi spinalis, iliocostalis, and longissimus are collectively known as the musculus erector spinae.

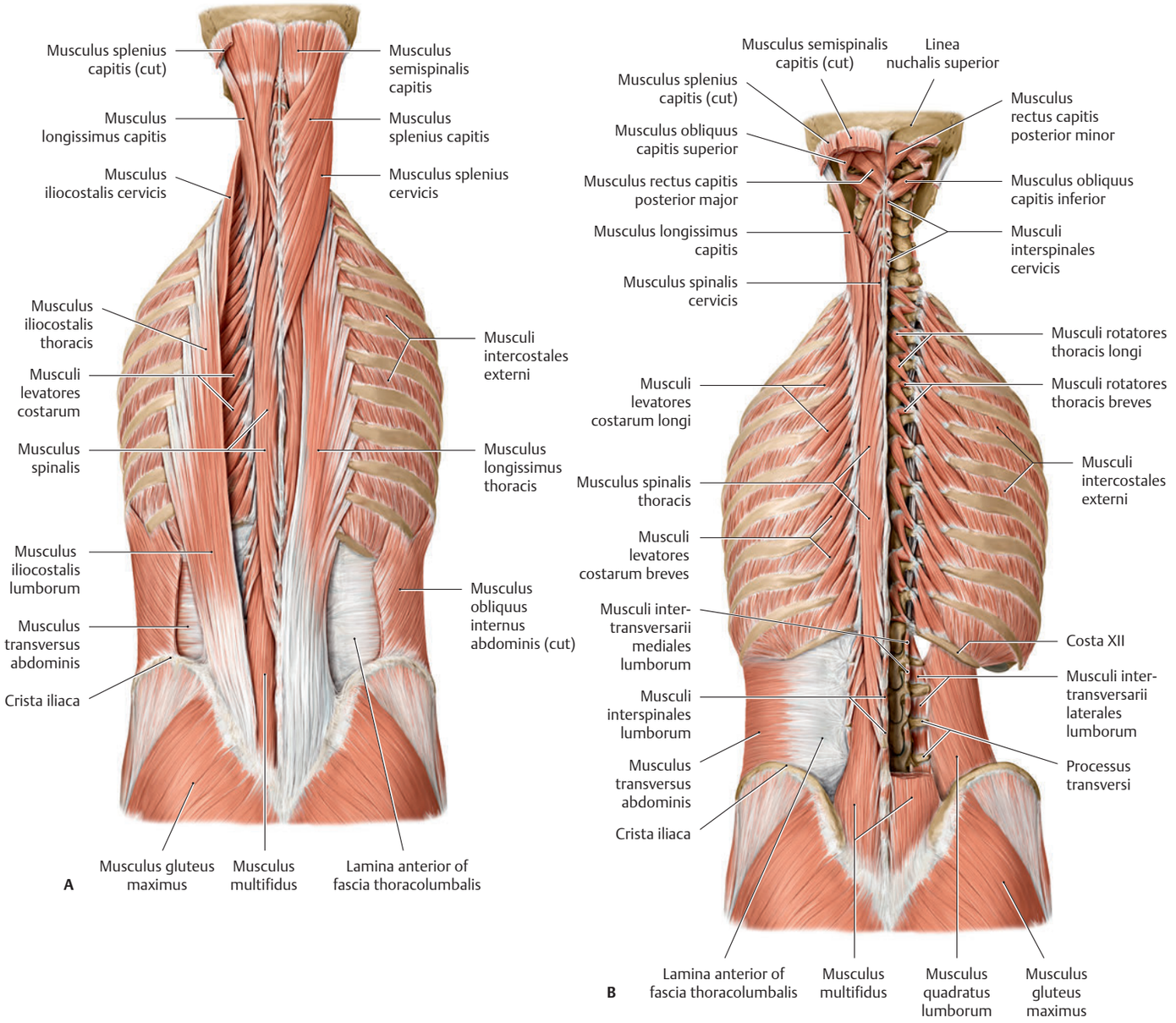


Fig. 11.23 **Musculi dorsi proprii**
Posterior view. These dissections reveal the layers of musculi dorsi proprii. The musculi iliocostalis, longissimus, and spinalis collectively form the musculus erector spinae. They lie deep to the lamina posterior of the fascia thoracolumbalis and cover the other intrinsic back muscles.

A *Removed on left side:* Musculus longissimus (except cervical portion), musculi splenii capitis and cervicis. *Removed on right side:* Musculus iliocostalis. Note the lamina anterior of the fascia thoracolumbalis, which gives origin to the musculi obliquus internus and transversus abdominis.

B *Removed on left side:* Musculi iliocostalis, longissimus, and obliquus internus abdominis. *Removed on right side:* Musculi erector spinae, multifidus, transversus abdominis, splenius capitis, and semispinalis capitis.

Muscles of the Posterior Neck

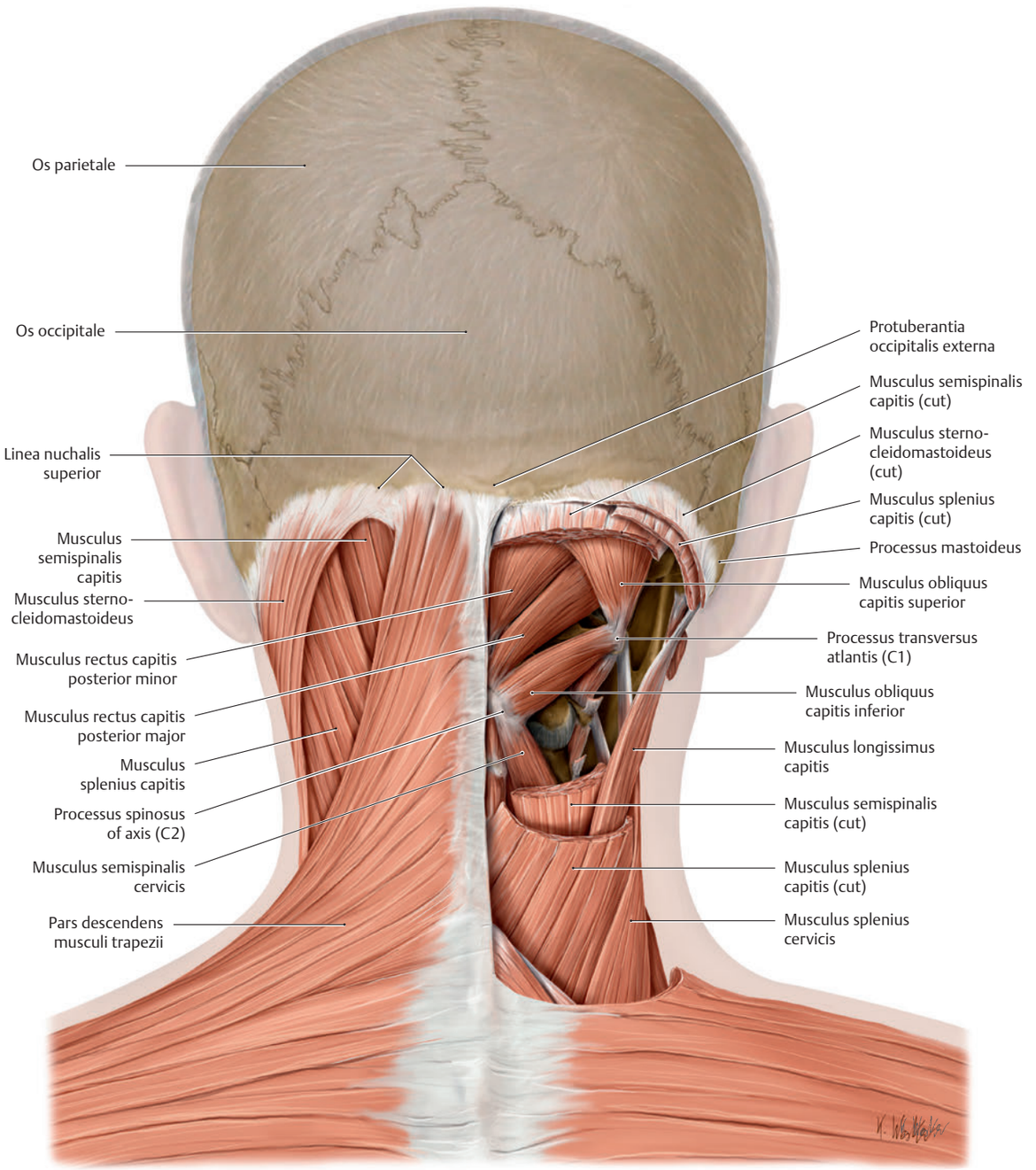
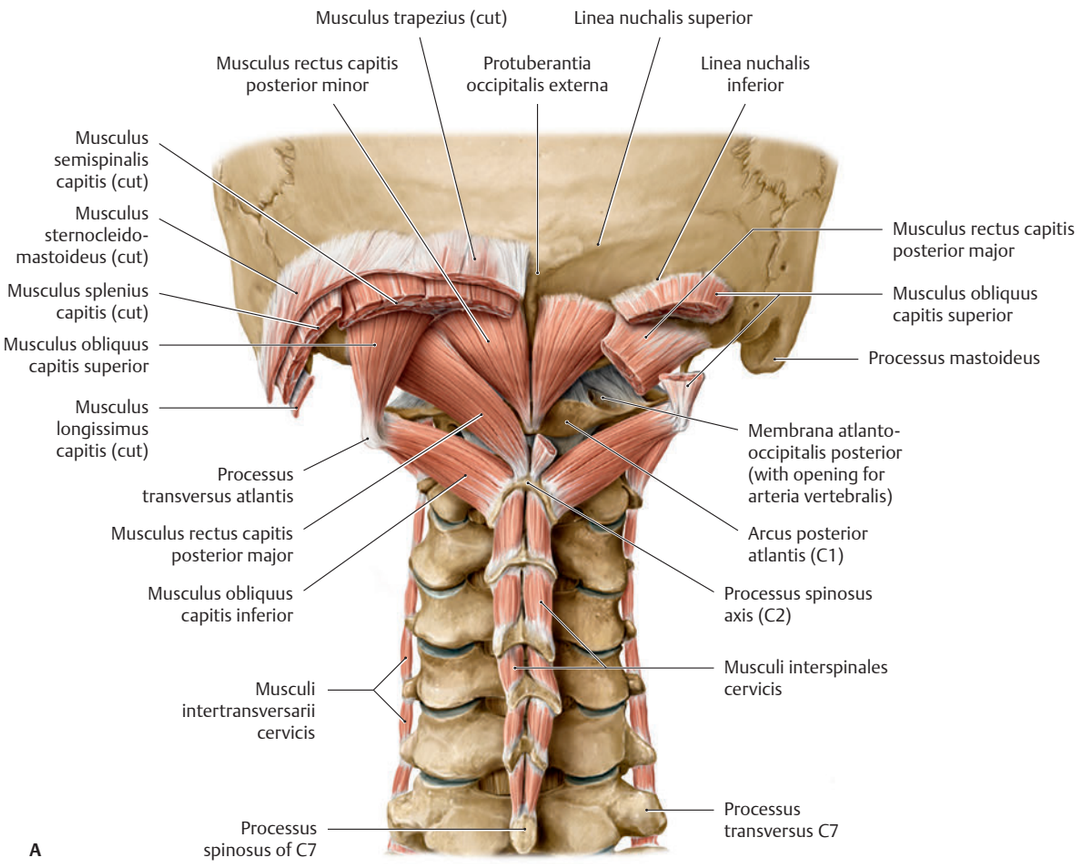


Fig. 11.24 **Muscles in the nuchal region**
Posterior view of nuchal region. As the neck is at the intersection of the trunk, head, and upper limb, its muscles can be divided according to embryonic origin, function, or location. Those muscles (extrinsic and intrinsic) located in the posterior neck are often referred to as the nuchal muscles. The nuchal muscles are further divided into short nuchal muscles, which are musculi dorsi proprii innervated by the rami posteriores of cervical nervi spinales. Based on location, the short nuchal muscles may also be referred to as musculi suboccipitales. The anterior and posterior vertebral muscles collectively move the craniovertebral joints.



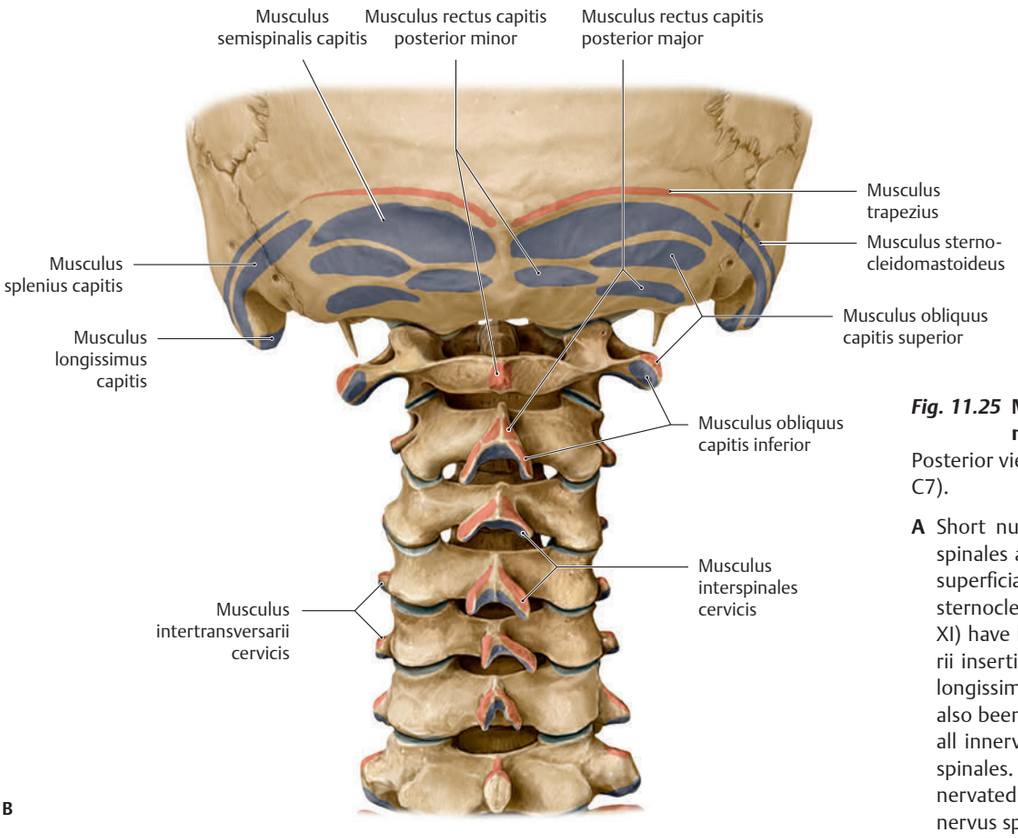


Fig. 11.25 **Muscle attachments in the nuchal region**

Posterior view of skull and cervical spine (C1–C7).

A Short nuchal muscles with musculi interspinales and intertransversarii cervicis. The superficial muscles (musculi trapezius and sternocleidomastoideus, innervated by CN XI) have been cut. The musculi dorsi proprii inserting on the skull (musculi splenius, longissimus, and semispinalis capitis) have also been cut. The musculi dorsi proprii are all innervated by rami posteriores of nervi spinales. The short nuchal muscles are innervated by the rami posteriores of the first nervus spinalis (nervus suboccipitalis).

B Muscle origins (red) and insertions (blue).

Musculi Dorsi Proprii (I): Musculi Erector Spinae & Interspinales

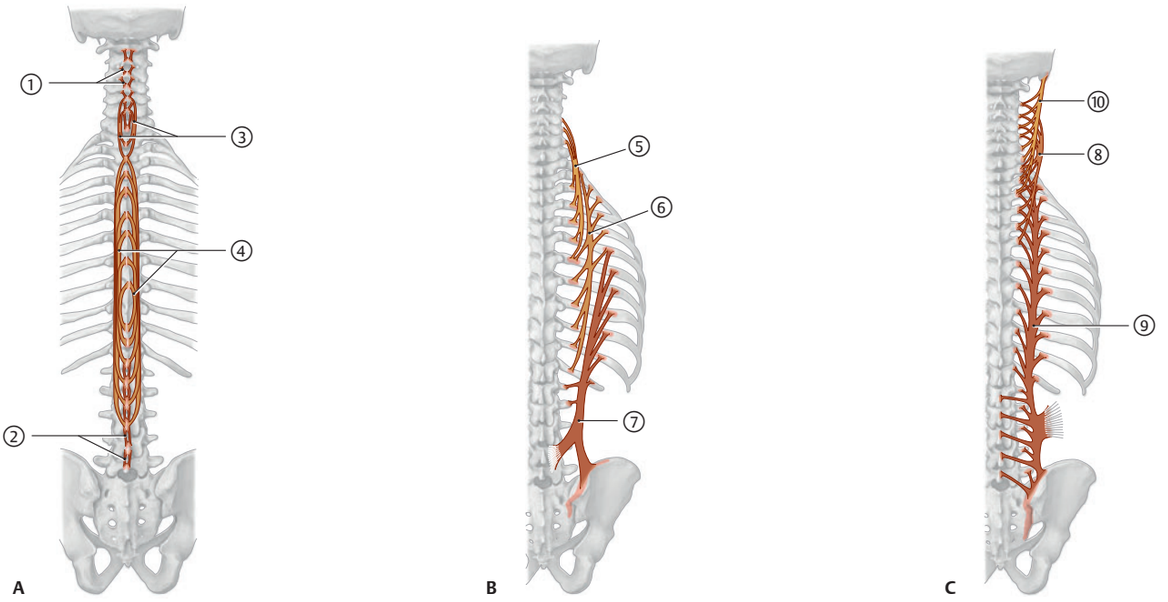


Fig. 11.26 **Musculi interspinales and erector spinae**
Schematic, posterior view.
A Musculi interspinales and spinalis. **B** Musculus iliocostalis. **C** Musculus longissimus.

Table 11.5 **Musculi erector spinae and interspinales**

Like all musculi dorsi proprii, these muscles are innervated by rami posteriores of nervi spinales. The musculi erector spinae and interspinales are innervated by lateral branches of the rami posteriores. The longissimus is innervated by nervi spinales C1–L5, the musculus iliocostalis by C8–L1.

Musculus		Origin	Insertion	Action
Mm. interspinales	① Mm. i. cervicis	C1–C7 (between processus spinosi of adjacent vertebrae)		Extends cervical spine
	② Mm. i. lumborum	L1–L5 (between processus spinosi of adjacent vertebrae)		Extends lumbar spine
M. spinalis*	③ M. s. cervicis	C5–T2 (processus spinosi)	C2–C5 (processus spinosi)	*Bilateral:* Extends spine *Unilateral:* Bends laterally to same side
	④ M. s. thoracis	T10–L3 (processus spinosi, lateral surface)	T2–T8 (processus spinosi, lateral surface)	
M. iliocostalis*	⑤ M. i. cervicis	3rd–7th ribs	C4–C6 (processus transversus)	
	⑥ M. i. thoracis	7th–12th ribs	1st–6th ribs	
	⑦ M. i. lumborum	Os sacrum; crista iliaca; lamina posterior of fascia thoracolumbalis	6th–12th ribs; lamina anterior of fascia thoracolumbalis; upper vertebrae lumbales (processus costiformes)	
M. longissimus*	⑧ M. l. cervicis	T1–T6 (processus transversi)	C2–C5 (processus transversi)	
	⑨ M. l. thoracis	Os sacrum; crista iliaca; L1–L5 (processus); lower vertebrae thoracicae (processus transversi)	2nd–12th ribs; T1–T12 (processus transversi) ; L1–L5 (processus costiformes)	
	⑩ M. l. capitis	T1–T3 (processus transversi); C4–C7 (processus transversi and articulares)	Os temporale (processus mastoideus)	*Bilateral:* Extends head *Unilateral:* Flexes and rotates head to same side

*The musculi spinalis, iliocostalis, and longissimus are collectively known as the musculus erector spinae. *Note:* The musculi iliocostalis and longissimus extend the entire spine. The musculus spinalis acts only on the cervical and thoracic spines.

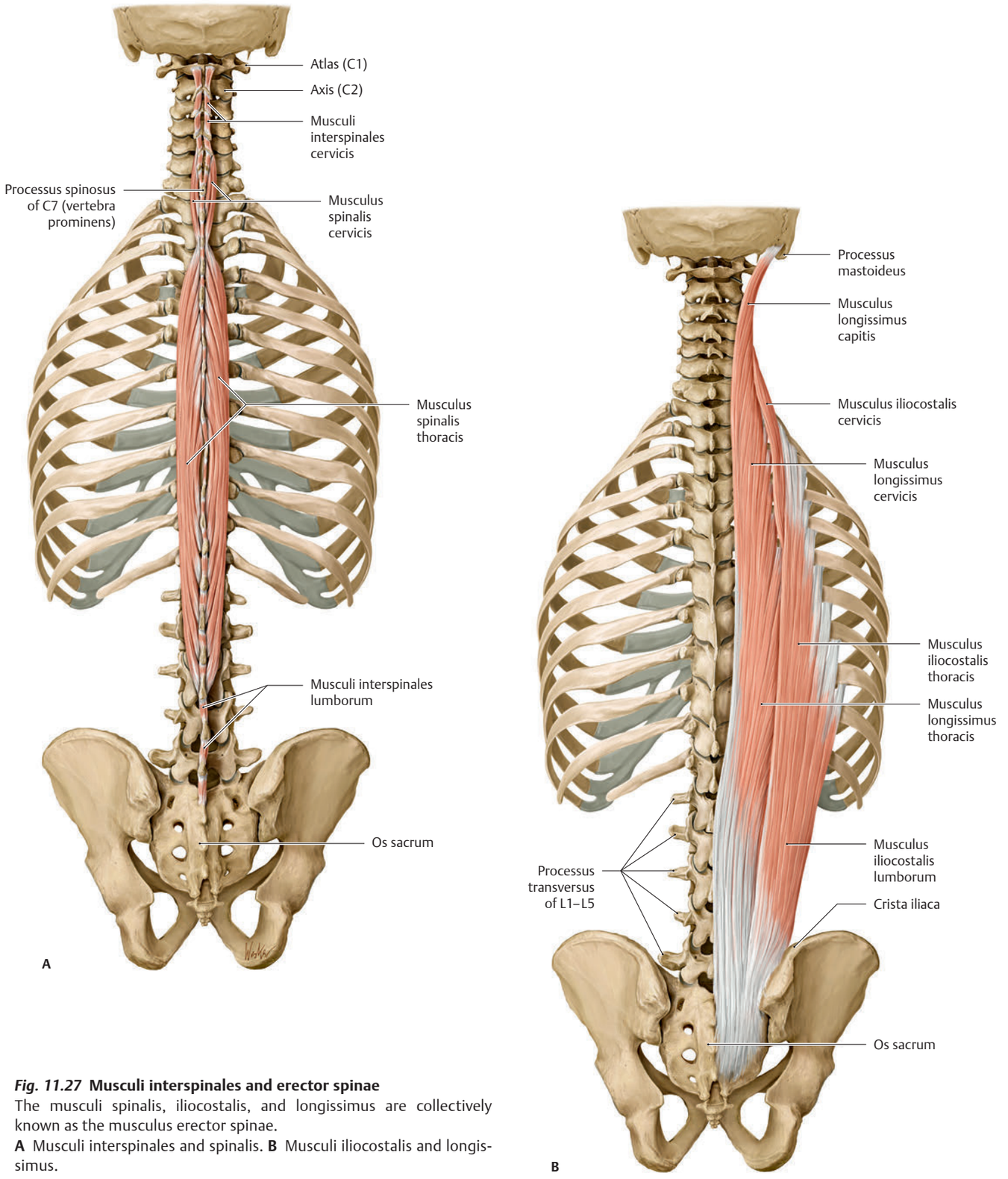


Fig. 11.27 **Musculi interspinales and erector spinae**
The musculi spinalis, iliocostalis, and longissimus are collectively known as the musculus erector spinae.
A Musculi interspinales and spinalis. **B** Musculi iliocostalis and longissimus.

Musculi Dorsi Proprii (II)

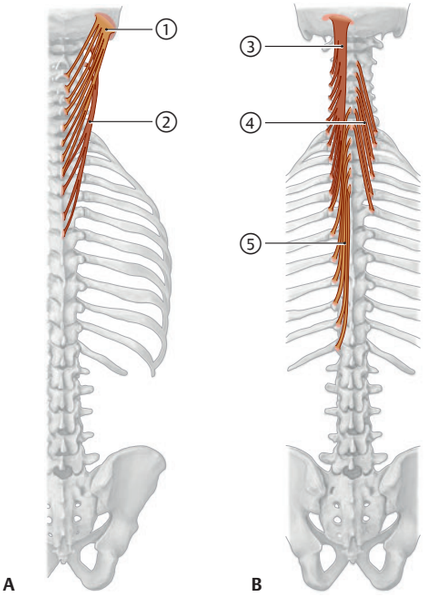


Fig. 11.28 **Musculi splenius and semispinalis**
Schematic, posterior view. **A** Musculus splenius. **B** Musculus semispinalis.

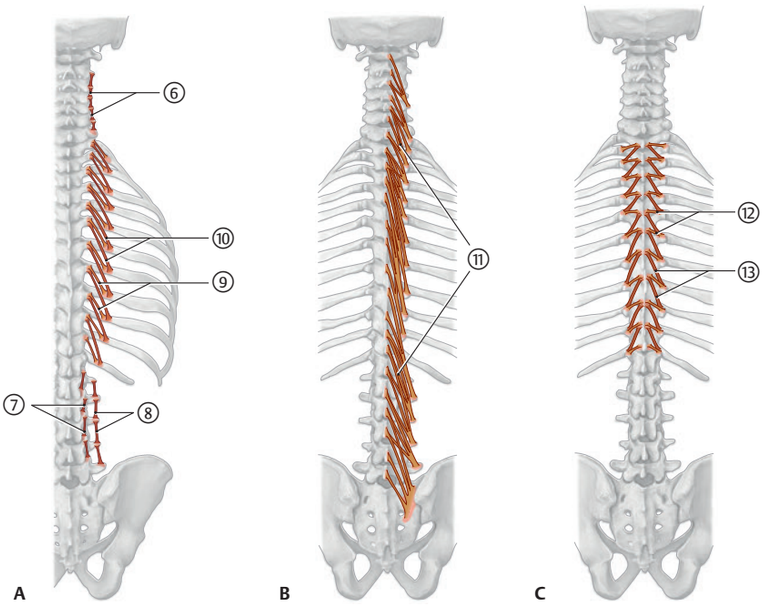


Fig. 11.29 **Musculi intertransversarii, levatores costarum, multifidus, and rotatores**
Schematic, posterior view. **A** Musculi intertransversarii and levatores costarum. **B** Musculus multifidus. **C** Musculi rotatores.

Table 11.6 **Musculi splenius, semispinalis, intertransversarii, levatores costarum, multifidus, and rotatores**

All musculi dorsi proprii are innervated by the rami posteriores of the nervi spinales except for the musculi intertransversii posteriores cervicis, which are innervated by the rami anteriores of the nervi spinales. The musculus splenius is innervated by nervi spinales C1–C6.

Musculus		Origin	Insertion	Action
M. splenius	① M. s. capitis	C7–T3 (processus spinosi)	Os occipitale (lateral linea nuchalis superior); os temporale (processus mastoideus)	*Bilateral:* Extends cervical spine and head *Unilateral:* Flexes and rotates head to same side
	② M. s. cervicis	T3–T6 (processus spinosi)	C1–C2 (processus transversi)	
M. semispinalis	③ M. s. capitis	C3–T6 (processus transversi)	Os occipitale (between lineae nuchales superior and inferior)	*Bilateral:* Extends cervical and thoracic spine and head (stabilizes craniovertebral joints) *Unilateral:* Bends head and cervical and thoracic spine to same side, rotates them to opposite side
	④ M. s. cervicis	T1–T6 (processus transversi)	C2–C7 (processus spinosi)	
	⑤ M. s. thoracis	T6–T12 (processus transversi)	C6–T4 (processus spinosi)	
Mm. intertransversarii	Mm. i. anteriores cervicis	C2–C7 (between tubercula anteriora of adjacent vertebrae)		*Bilateral:* Stabilizes and extends cervical and lumbar spine *Unilateral:* Bends cervical and lumbar spine laterally to same side
	⑥ Mm. i. posteriores cervicis	C2–C7 (between tubercula posteriora of adjacent vertebrae)		
	⑦ Mm. i. mediales lumborum	L1–L5 (between processus mammillares of adjacent vertebrae)		
	⑧ Mm. i. laterales lumborum	L1–L5 (between processus costiformes of adjacent vertebrae)		
Mm. levatores costarum	⑨ Mm. l.c. brevis	C7–T11 (processus transversi)	Angulus costae of next lower rib	*Bilateral:* Extends thoracic spine *Unilateral:* Bends thoracic spine to same side, rotates thoracic spine to opposite side
	⑩ Mm. l.c. longi		Angulus costae of second lower rib	
⑪ Musculus multifidus		C4–T4 (processus transversi and articulares), L1–L5 (processus mammillares), os ilium, and os sacrum superomedially to processus spinosus of vertebra two to four levels higher		*Bilateral:* Extends spine *Unilateral:* Flexes spine to same side, rotates spine to opposite side
Musculi rotatores	⑫ Mm. rr. breves	T1–T12 (between processus transversus and processus spinosi of next higher vertebra)		*Bilateral:* Extends thoracic spine *Unilateral:* Flexes spine to same side, rotates spine to opposite side
	⑬ Mm. rr. longi	T1–T12 (between processus transversus and processus spinosi of vertebra two levels higher)		

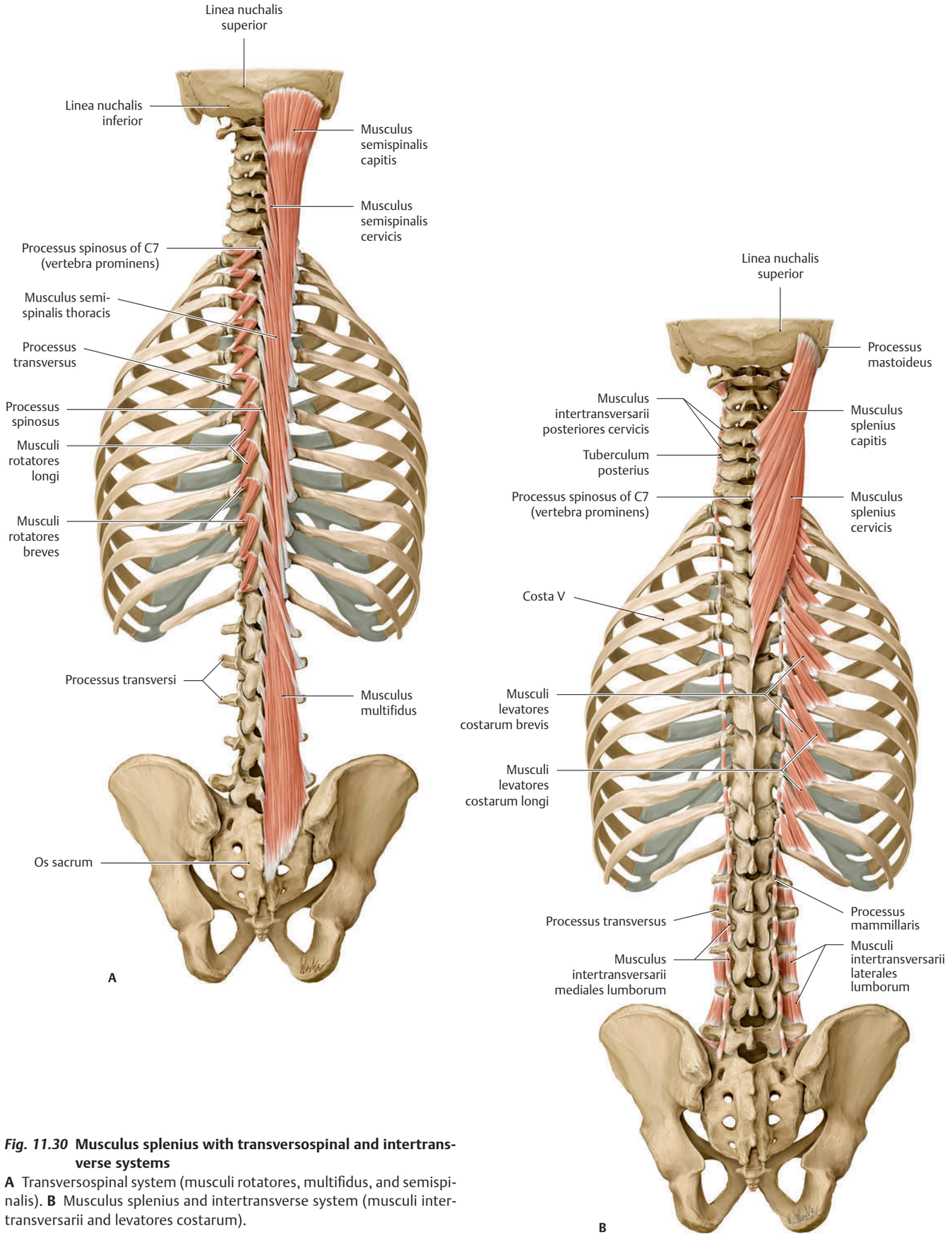


Fig. 11.30 **Musculus splenius with transversospinal and intertransverse systems**

A Transversospinal system (musculi rotatores, multifidus, and semispinalis). **B** Musculus splenius and intertransverse system (musculi intertransversarii and levatores costarum).

Musculi Dorsi Proprii (III): Short Nuchal & Craniovertebral Joint Muscles

Fig. 11.31 **Short nuchal and craniovertebral joint muscles**
Schematic, posterior view. The short nuchal and craniovertebral joint muscles are musculi dorsi proprii that are innervated by the ramus posterior of the first spinal nerve (nervus suboccipitalis). These muscles contribute to the extension of the articulatio atlantooccipitalis and rotation about the articulatio atlantoaxialis.

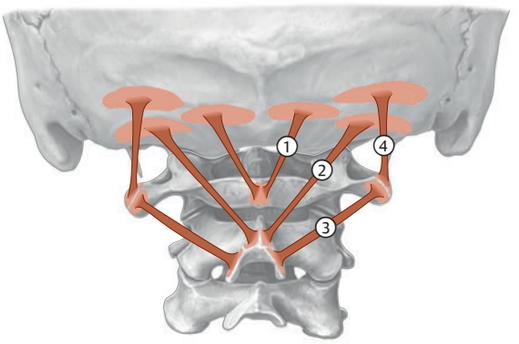


Table 11.7 **Short nuchal muscles**

Musculus		Origin	Insertion	Innervation	Action
Musculus rectus capitis posterior	① M.r.c.p. minor	C1 (tuberculum posterius)	Linea nuchalis inferior (inner ⅓)	C1 nervus spinalis (nervus suboccipitalis), ramus posterior	*Bilateral:* Extends head *Unilateral:* Rotates head to same side
	② M.r.c.p. major	C2 (processus spinosus)	Linea nuchalis inferior (middle ⅓)		
Musculus obliquus capitis	③ M.o.c. inferior	C2 (processus spinosus)	C1 (processus transversus)		
	④ M.o.c. superior	C1 (processus transversus)	Above the insertion of the musculus rectus capitis posterior major or linea nuchalis inferior (middle ⅓)		*Bilateral:* Extends head *Unilateral:* Tilts head to same side; rotates head to opposite side

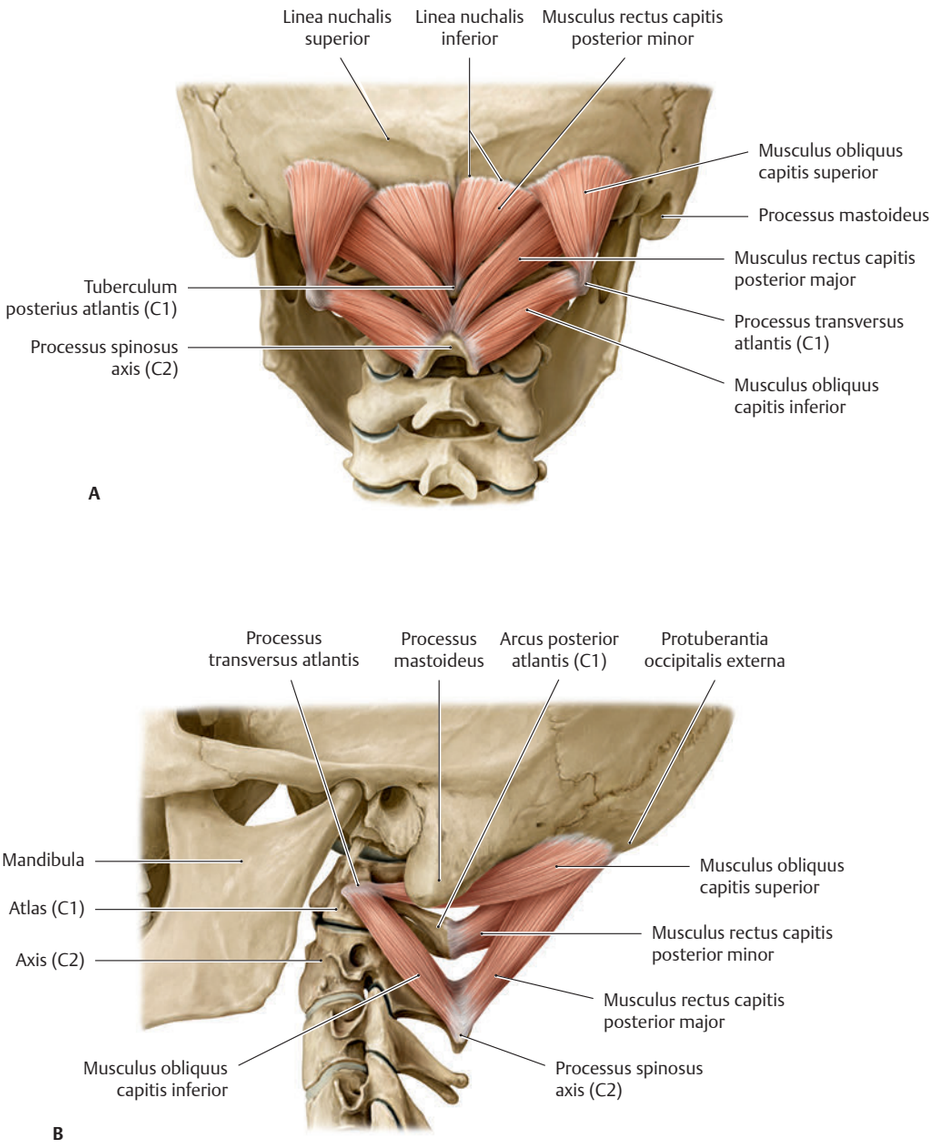


Fig. 11.32 **Musculi suboccipitales**
A Posterior view. **B** Left lateral view.
The musculi suboccipitales collectively act on the craniovertebral joints. The musculi suboccipitales are the musculi rectus capitis posterior major, rectus capitis posterior minor, obliquus capitis inferior, and obliquus capitis superior. The ramus posterior of the first cervical nervus spinalis innervates all four musculi suboccipitales. Note: The suboccipital triangle is located between the musculus rectus capitis posterior major, the obliquus capitis superior, and the musculus obliquus capitis inferior.

Prevertebral & Scalene Muscles

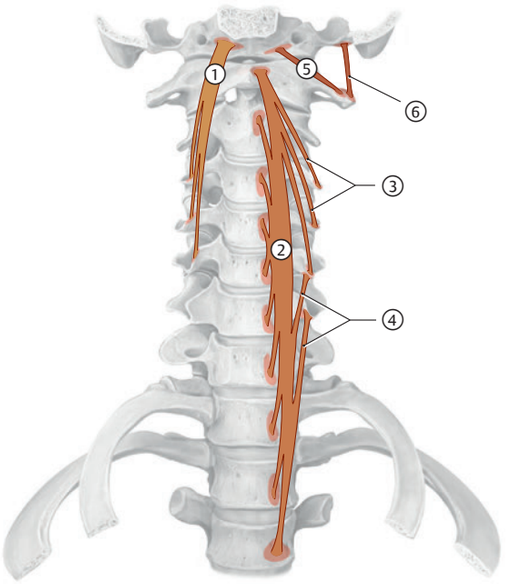


Fig. 11.33 **Prevertebral muscles**
Schematic, anterior view.

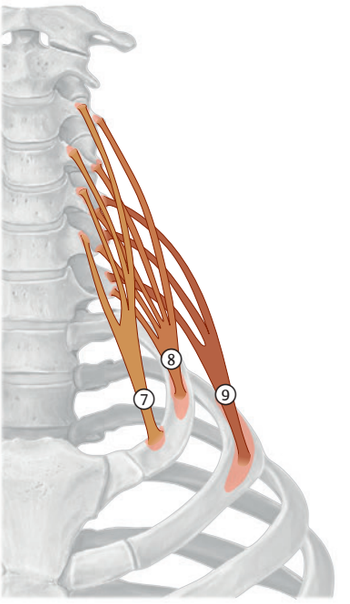


Fig. 11.34 **Scalene muscles**
Schematic, anterior view.

Table 11.8 **Prevertebral and scalene muscles**

Musculus		Origin	Insertion	Innervation	Action
① Musculus longus capitis		C3–C6 (tubercula anteriora)	Pars basilaris ossis occipitalis	Plexus cervicalis, direct branches (C1–C3)	*Bilateral:* Flexes head *Unilateral:* Tilts and slightly rotates head to same side
Musculus longus colli	② Pars verticalis (cervicalis)	C5–T3 (anterior surfaces of corpora vertebrarum)	C2–C4 (anterior surfaces)	Rami anteriores of C2–C6 spinal nn.	*Bilateral:* Flexes cervical spine *Unilateral:* Tilts and slightly rotates cervical spine to same side
	③ Pars obliqua superior	C3–C5 (tubercula anteriora)	C1 (tuberculum anterius)		
	④ Pars obliqua inferior	T1–T3 (anterior surfaces of corpora vertebrarum)	C5–C6 (tubercula anteriora)		
Musculus rectus capitis	⑤ Musculus rectus capitis anterior	C1 (massa lateralis atlantis)	Pars basilaris ossis occipitalis	Ramus anterior of C1 spinal n. (nervus suboccipitalis)	*Bilateral:* Flexion at articulatio atlantooccipitalis *Unilateral:* Lateral flexion at articulatio atlantooccipitalis
	⑥ Musculus rectus capitis lateralis	C1 (processus transversus)	Os occipitale (pars basilaris, lateral to condyli occipitales)		
Musculi scaleni	⑦ Musculus scalenus anterior	C3–C6 (tubercula anteriora)	1st rib (tuberculum musculi scaleni anterioris)	Rami anteriores of cervical spinal nn.	*With ribs mobile:* Elevate upper ribs (in inspiration) *With ribs fixed:* Bend cervical spine to same side (unilateral contraction); flex cervical spine (bilateral contraction)
	⑧ Musculus scalenus medius	C1 and C2 (processus transversi); C3–C7 (tubercula posteriora)	1st rib (posterior to sulcus arteriae subclaviae)		
	⑨ Musculus scalenus posterior	C5–C7 (tubercula posteriora)	2nd rib (outer surface)		

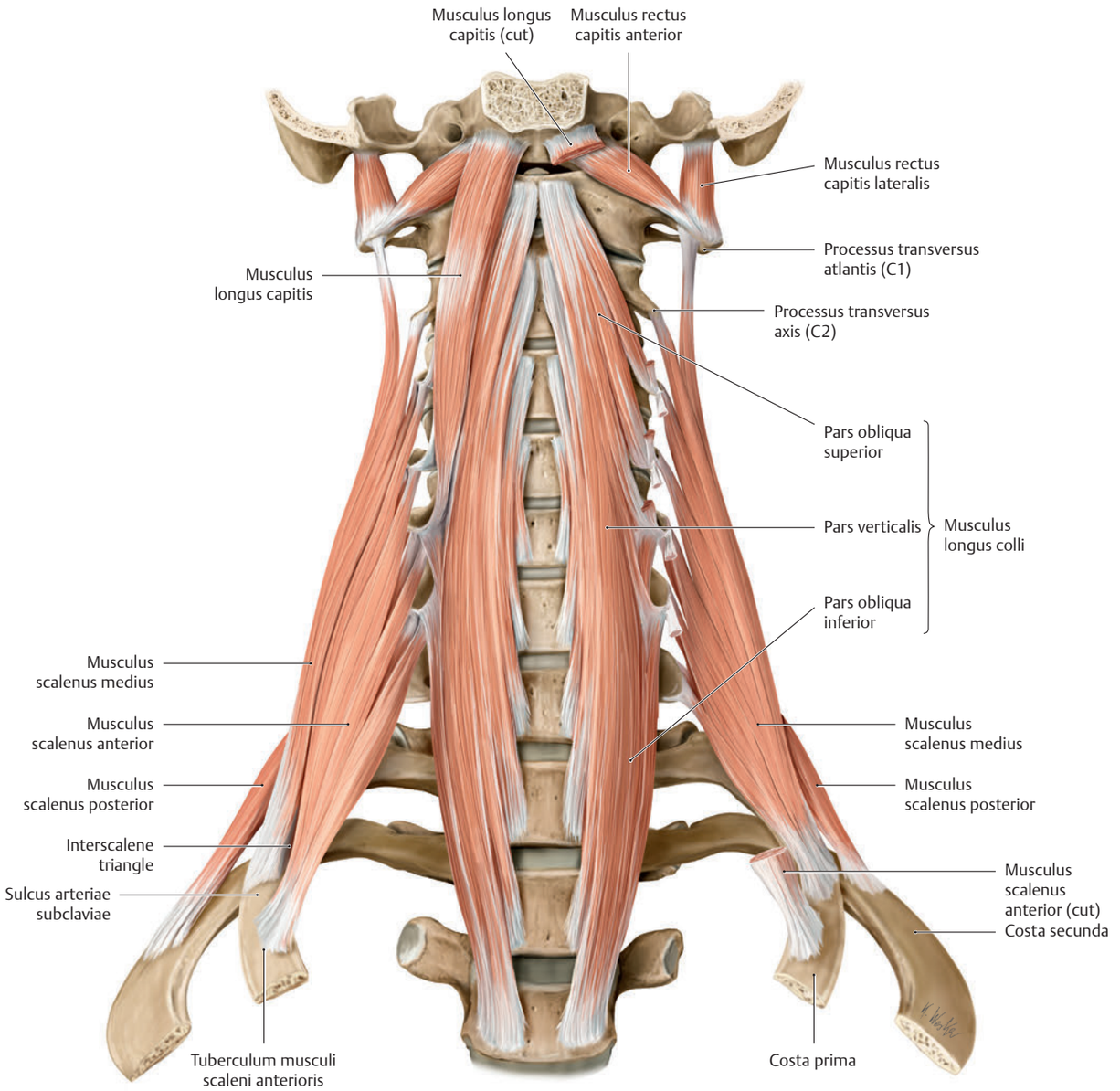


Fig. 11.35 **Prevertebral and scalene muscles**
Anterior view. *Removed on left side:* Musculi longus capitis and scalenus anterior. The prevertebral (anterior vertebral) muscles are the musculi longus colli, longus capitis, rectus capitis lateralis, and rectus capitis anterior. The musculi scaleni anterior, medius, and posterior are the lateral vertebral muscles. The anterior and lateral vertebral muscles are innervated by the rami anteriores of the cervical nervi spinales.

Musculi Suprahyoidei & Infrahyoidei

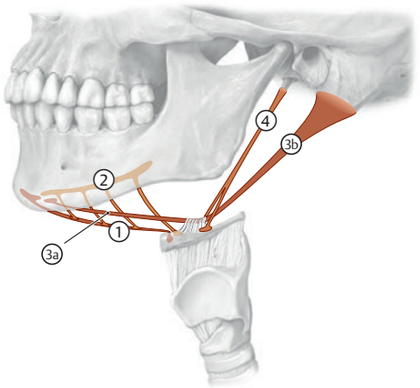


Fig. 11.36 **Musculi suprahyoidei**
Schematic, left lateral view.

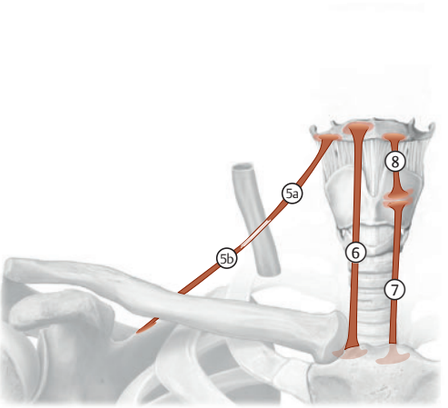


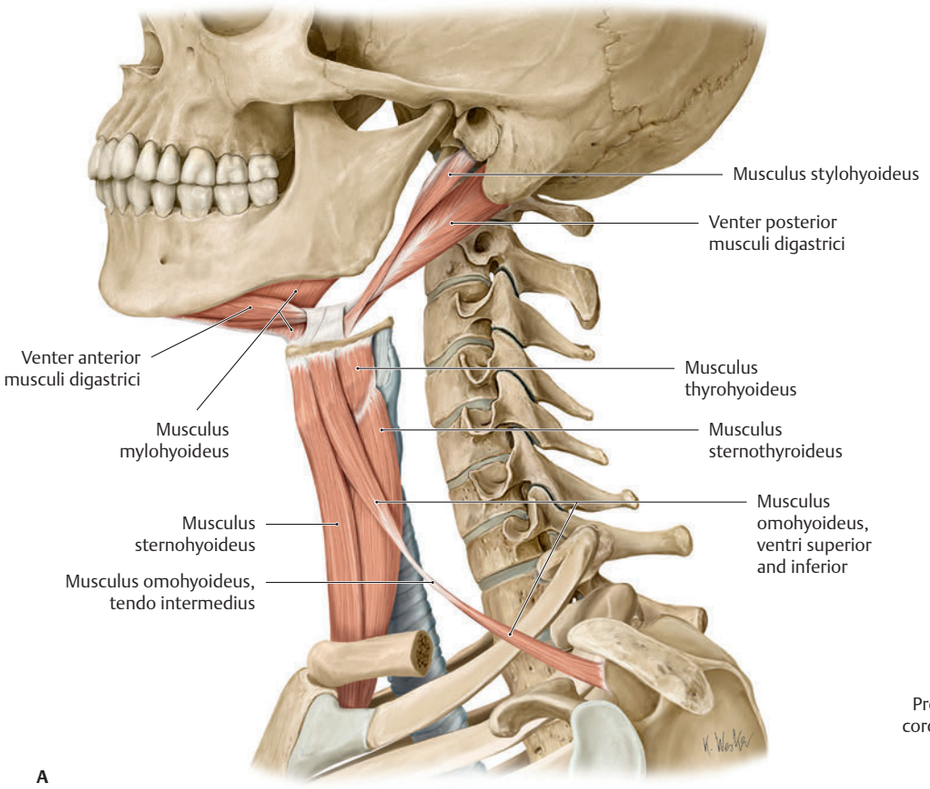
Fig. 11.37 **Musculi infrahyoidei**
Schematic, anterior view.

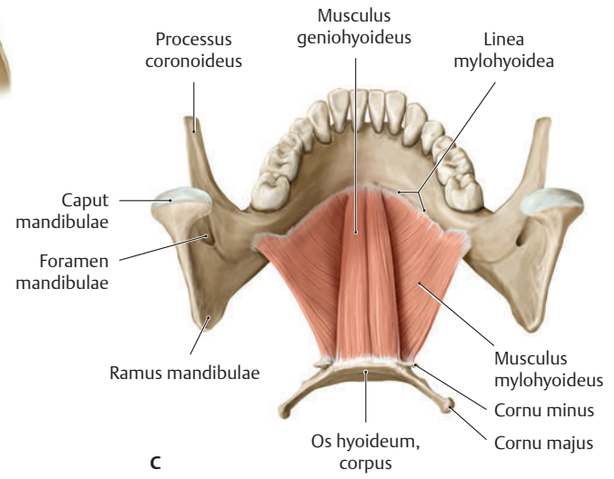
Table 11.9 **Musculi suprahyoidei and infrahyoidei**

Muscle	Origin	Insertion	Innervation	Action
Musculi suprahyoidei				
① Musculus geniohyoideus	Mandibula (spina mentalis inferior)	Os hyoideum	Ramus anterior of C1 via nervus hypoglossus (CN XII)**	Draws os hyoideum forward (during swallowing); assists in opening mandibula
② Musculus mylohyoideus	Mandibula (linea mylohyoidea)	Os hyoideum (via median tendon of insertion, the linea mylohyoidea)	Nervus mylohyoideus (from CN V_3)	Tightens and elevates oral floor; draws os hyoideum forward (during swallowing); assists in opening mandibula and moving it side to side (mastication)
③a Venter anterior musculi digastrici	Mandibula (fossa digastrica)	Os hyoideum (via a tendo intermedius with a fibrous loop)		Elevates os hyoideum (during swallowing); assists in opening mandibula
③b Venter posterior musculi digastrici	Os temporale (incisura mastoidea, medial to processus mastoideus)		Nervus facialis (CN VII)	
④ Musculus stylohyoideus	Os temporale (processus styloideus)	Os hyoideum (via a split tendo)		
Musculi infrahyoidei				
⑤a Venter superior musculi omohyoidei	Tendo intermedius of musculus omohyoideus	Os hyoideum	Ansa cervicalis of plexus cervicalis (C1–C3)	Depresses (fixes) os hyoideum; draws larynx and os hyoideum down for phonation and terminal phases of swallowing*
⑤b Venter inferior musculi omohyoidei	Scapula (margo superior, medial to incisura scapulae)	Intermediate tendo of musculus omohyoideus		
⑥ Musculus sternohyoideus	Manubrium sterni and articulatio sternoclavicularis (posterior surface)	Os hyoideum		
⑦ Musculus sternothyroideus	Manubrium sterni (posterior surface)	Cartilago thyroidea (linea obliqua)	Ansa cervicalis C2, C3	
⑧ Musculus thyrohyoideus	Cartilago thyroidea (linea obliqua)	Os hyoideum	Ramus anterior of C1 via nervus hypoglossus (CN XII)	Depresses and fixes os hyoideum; raises the larynx during swallowing

*The musculus omohyoideus also tenses the fascia cervicalis (with an tendo intermedius). The tendo intermedius is attached to the clavicula, pulling the musculus omohyoideus into a more pronounced triangle.

**C1 ramus anterior fibers travel with the nervus hypoglossus for part of its pathway to target muscles.





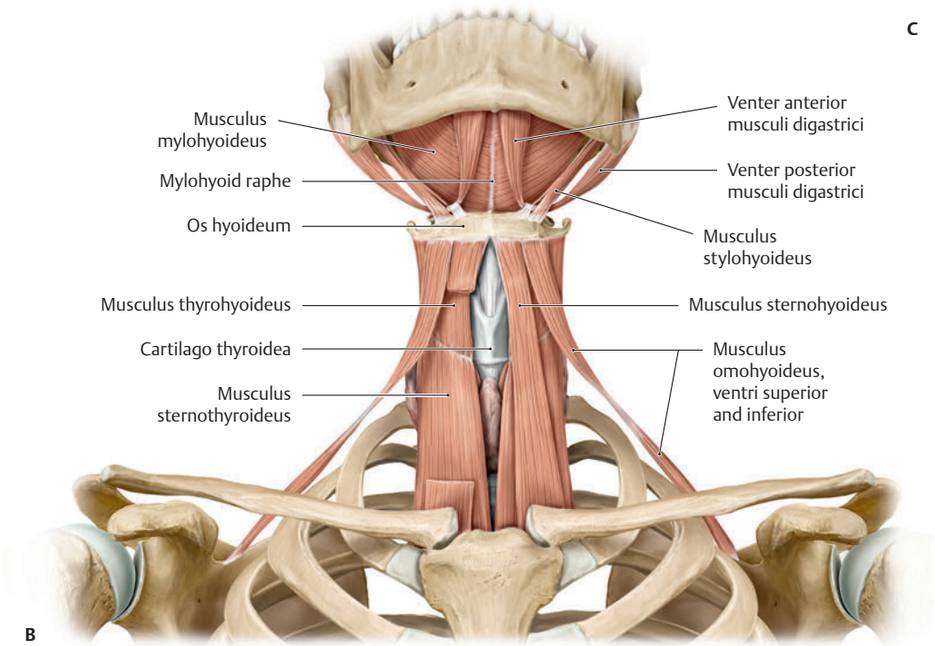


Fig. 11.38 **Musculi suprahyoidei and infrahyoidei**

A Left lateral view. **B** Anterior view. **C** Posterosuperior view.

The musculus mylohyoideus and venter anterior musculi digastrici are derived from the first pharyngeal arch and are therefore supplied by the nervus trigeminus (CN V). The nervus mylohyoideus arises from the mandibular division of CN V before the majority of fibers enter the foramen mandibulae as the nervus alveolaris inferior. The musculus stylohyoideus and venter posterior musculi digastrici are derived from the second pharyngeal arch and are therefore supplied by the nervus facialis (CN VII). The remainder of the musculi suprahyoidei and infrahyoidei muscles are supplied by the rami anteriores of the cervical nervi spinales. Fibers from the ramus anterior of C1 travel with the nervus hypoglossus (CN XII) to the musculi geniohyoideus and thyrohyoideus. Fibers from the rami anteriores of C1–C3 combine to form the ansa cervicalis, which gives off branches to the musculi omohyoideus, sternohyoideus, and sternothyroideus.

Arteries & Veins of the Neck

Fig. 12.1 **Arteries of the neck**
Left lateral view. The structures of the neck are supplied by branches of the arteria carotis externa and the arteria subclavia (the arteria carotis interna gives off no branches in the neck). The arteria carotis communis is enclosed in a fascial sheath (vagina carotica) along with the vena jugularis and nervus vagus. The arteria vertebralis ascends through the foramina transversaria of the vertebrae cervicales (C6–C1).
The arteria carotis interna is often affected by atherosclerosis, a hardening of the arterial walls due to plaque formation. These plaques can cause stenosis, thrombosis, and embolization, which could result in vision loss, transient ischemic attacks (TIAs), or stroke.

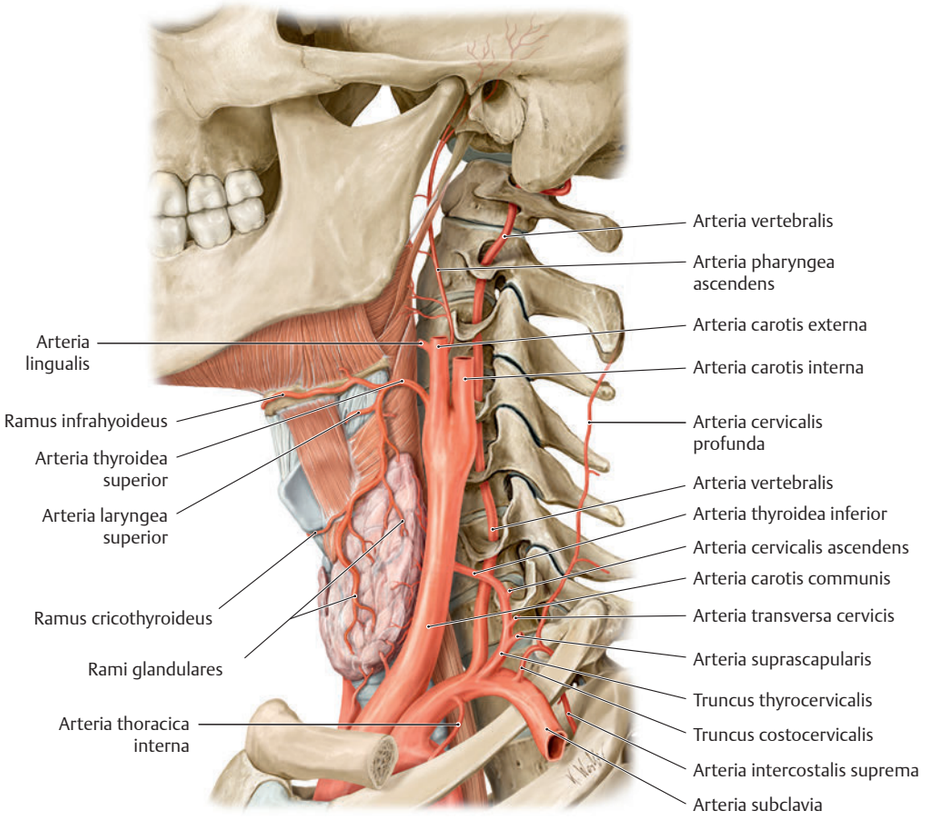


Table 12.1 **Arteries of the neck**

For a complete treatment of the arteries of the head and neck, see **Chapter 3**.

Artery	Branches	Secondary branches*	
Arteria carotis externa	Arteria thyroidea superior	Arteria laryngea superior, rami cricothyroideus, infrahyoideus, and sternocleidomastoideus	
	Arteria pharyngea ascendens	Rami pharyngeales, arteria tympanica inferior, and arteria meningea posterior	
	Arteria lingualis	Rami suprahyoideus and dorsalis linguae, arteriae profunda linguae, and sublingualis	
	Arteria facialis	Arteria palatina ascendens, ramus tonsillaris, rami glandulares, and arteria submentalis	
	Arteria occipitalis	Rami sternocleidomastoideus, descendens, mastoideus, auricularis, and meningeus	
	Arteria auricularis posterior	Arteria stylomastoidea and ramus auricularis	
	Arteria temporalis superficialis	(Branching occurs on the face)	
	Arteria maxillaris	(Branches within the fossa infratemporalis [see pp. 158 and 159])	
Arteria subclavia	Arteria vertebralis	Arteriae spinales and rami musculares	
	Truncus thyrocervicalis	Arteria thyroidea inferior	Arteria laryngea inferior, rami tracheales and, oesophageales, and arteria cervicalis ascendens
		Arteria suprascapularis	
		Arteria transversa cervicis	Superficial and deep branches
	Arteria thoracica interna	(Branching occurs within the thorax)	
	Arteria dorsalis scapulae	(When present, it supplies the territory of the deep branch of the transverse cervical a.)	
	Truncus costocervicalis	Arteria cervicalis profunda	
		Arteria intercostalis suprema	

*Only branches that arise in the neck are listed here.

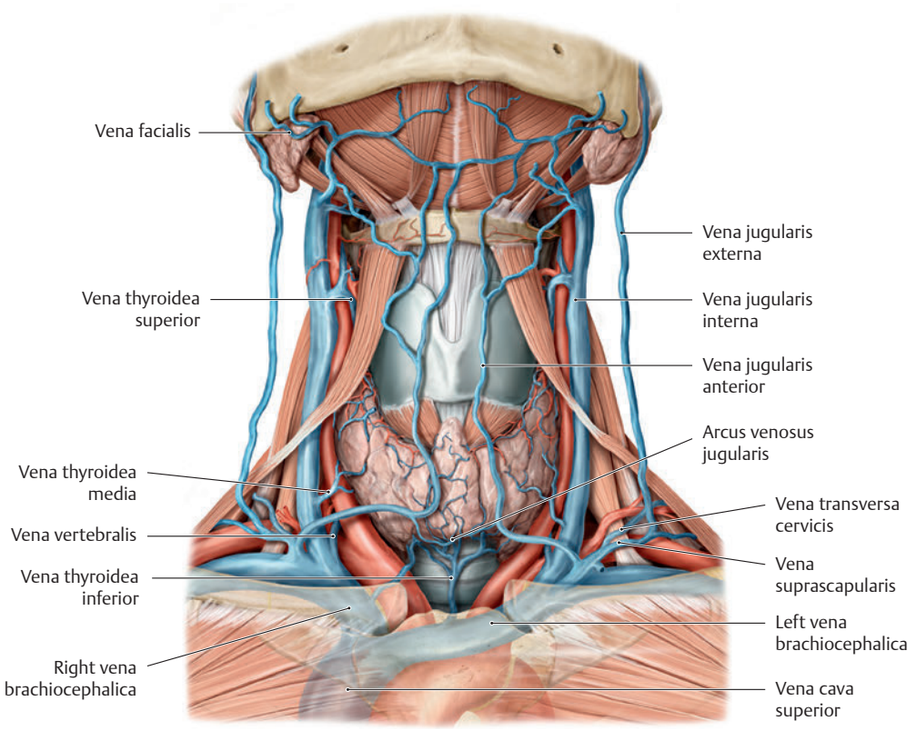


Fig. 12.2 **Veins of the neck**
Anterior view. The veins of the head and neck drain to the vena cava superior via the right and left venae brachiocephalicae. The large vena jugularis interna combines with the vena subclavia to form the vena brachiocephalica on each side. The vena jugularis interna is located within the vagina carotica. It receives blood from the anterior neck and the interior of the skull. The vena subclavia receives blood from the neck via the venae jugularis externa and anterior, which are located within the lamina superficialis fasciae cervicalis. *Note:* The plexus thyroideus impar and venae vertebrales typically drain directly into the venae brachiocephalicae.

Table 12.2 **Veins of the neck**

For a complete treatment of the veins of the head and neck, see **Chapter 3**.			
Right and left venae brachiocephalicae*	Vena jugularis interna	Sinus sigmoideus, sinus petrosus inferior, venae pharyngeae, occipitalis, (common) vena facialis, vena lingualis, and venae thyroidea superior and mediae	
	Vena subclavia	Vena jugularis externa	Vena jugularis posterior, vena jugularis anterior, venae transversae cervicis, and vena suprascapularis**
	Vena vertebralis	Internal and external vertebral venous plexuses; vena vertebralis anterior and vena cervicalis profunda	
	Vena thyroidea inferior	Plexus thyroideus impar	

*The vena brachiocephalica is formed by the joining of its two primary tributaries, the vena jugularis interna and the vena subclavia. Only tributaries within the neck are listed above.
**The tributaries of the vena jugularis externa may on occasion drain directly into the vena subclavia.

Plexus Cervicalis

The neck receives innervation from the cervical nervi spinalis as well as three nervi craniales: nervus glossopharyngeus (CN IX), nervus vagus (CN X), and nervus accessorius (CN XI). CN IX and X innervate the pharynx and larynx; CN XI provides motor innervation to the musculi trapezius and sternocleidomastoideus. The course and distribution of the nervi craniales are described in **Chapter 4**.

Fig. 12.3 **Plexus cervicalis**

The rami anteriores of nervi spinalis C1–C4 emerge from the foramina intervertebralia along the processus transversi of the vertebrae cervicales. They emerge between the musculi scaleni anterior and posterior and give off short direct branches to the musculi scaleni and musculi recti capitis anterior before coursing anteriorly to form the plexus cervicalis.

Motor fibers: Motor fibers from C1 course with the nervus hypoglossus (CN XII). Certain fibers continue with the nerve to innervate the musculi thyrohyoideus and geniohyoideus. The remainder leave CN XII to form the radix superior of the ansa cervicalis. The radix inferior is formed by motor fibers from C2 and C3. The ansa cervicalis innervates the musculi omohyoideus, sternothyroideus, and sternohyoideus. Most motor fibers from C4 descend as the nervus phrenicus, which innervates the diaphragm.

Sensory fibers: The sensory fibers of C2–C4 emerge from the plexus cervicalis as peripheral nerves. (*Note:* The sensory fibers of C1 go to the meninges.) These peripheral sensory nerves emerge from Erb's point and provide sensory innervation to the anterolateral neck.

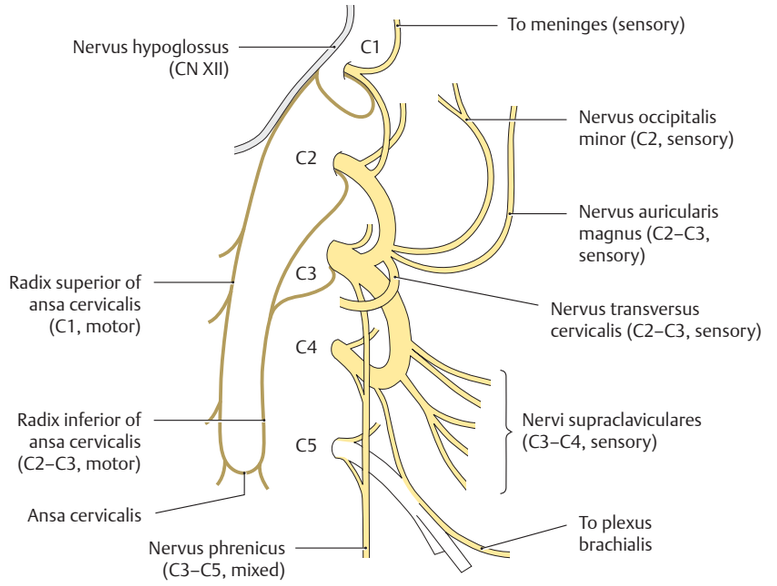


Table 12.3 **Branches of the plexus cervicalis**

	Sensory branches	Sensory function	Motor branches	Motor function
C1	—	—	Forms ansa cervicalis (motor part of plexus cervicalis) and separate motor branches of CI	Ansa cervicalis innervates musculi infrahyoidei (except musculus thyrohyoideus). CI innervates musculi thyrohyoideus and geniohyoideus in separate branches traveling with CN XII
C2	Nervus occipitalis minor	Form sensory part of plexus cervicalis; innervate anterior and lateral neck		
C2–C3	Nervus auricularis magnus			
	Nervus transversus cervicalis			
C3–C4	Nervi supraclaviculares		Contribute to nervus phrenicus**	Innervate diaphragma and pericardium**

** The anterior roots of C3–C5 combine to form the nervus phrenicus.

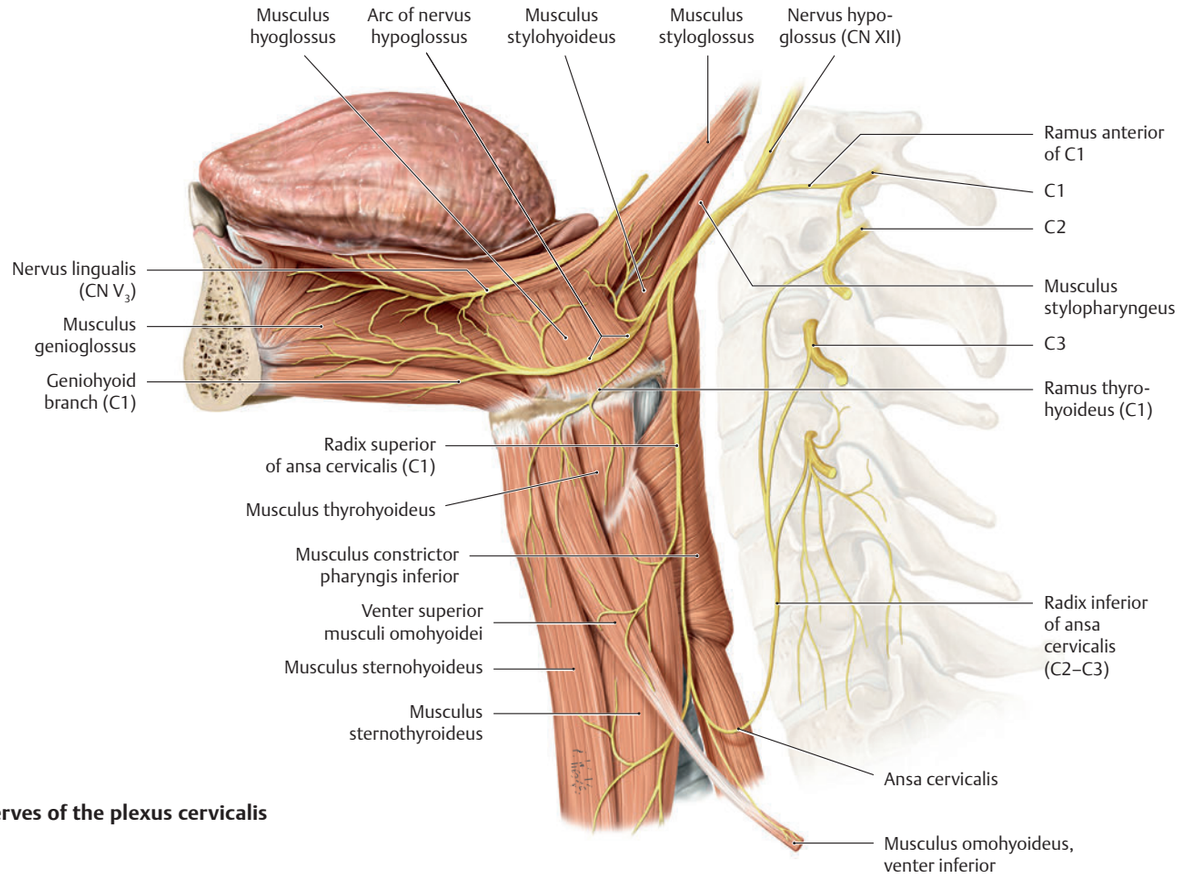


Fig. 12.4 **Motor nerves of the plexus cervicalis**
Left lateral view.

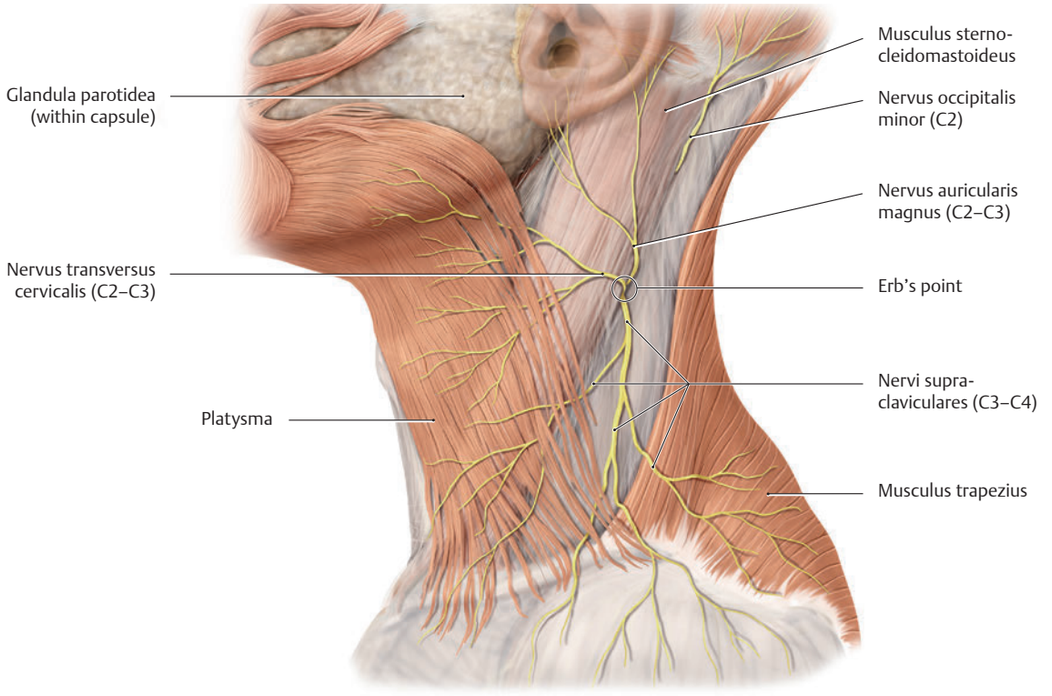


Fig. 12.5 **Sensory nerves of the plexus cervicalis**
Left lateral view.

Cervical Regions (Trigona)

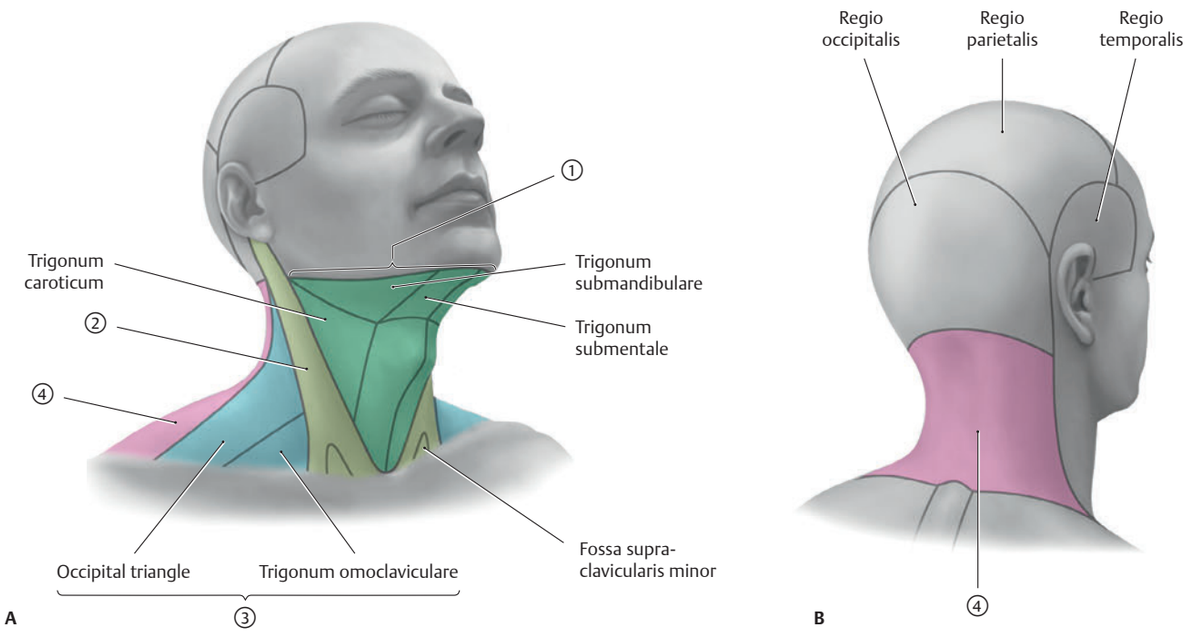
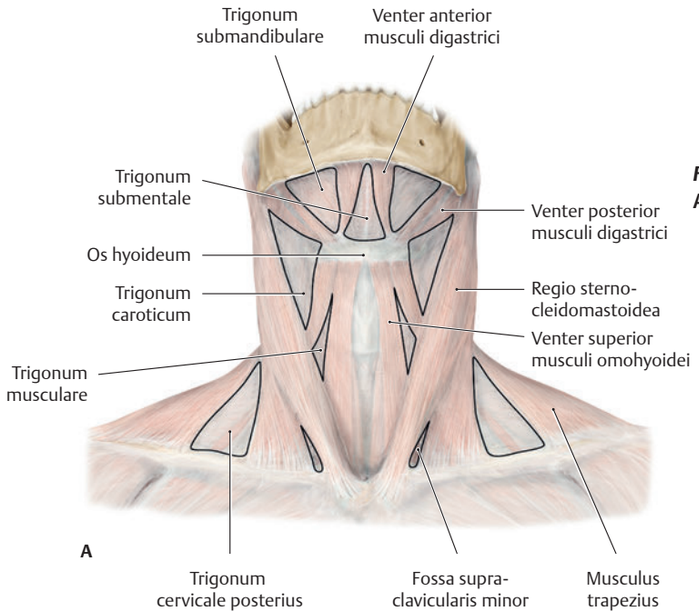


***Fig. 12.6* Cervical regions**
A Right lateral oblique view. **B** Left posterior oblique view.
For descriptive purposes, the anterolateral neck is divided into a trigonum cervicale anterius and a posterius, separated by the musculus sternocleidomastoideus. The posterior portion of the neck is referred to as the nuchal region.

***Table 12.4* Cervical regions**

Region	Subdivision
① Regio cervicalis anterior (trigonum cervicale anterius): Bounded by the midline, mandibula, and musculus sternocleidomastoideus.	Trigonum submandibulare: Bounded by the mandibula and the ventri of the musculus digastricus.
	Trigonum caroticum: Bounded by the musculus sternocleidomastoideus, venter superior of the musculus omohyoideus, and venter posterior of the musculus digastricus.
	Trigonum musculare: Bounded by the musculi sternocleidomastoideus, omohyoideus (venter superior), and sternohyoideus.
	Trigonum submentale: Bounded by the ventri anteriores of the musculus digastricus, the os hyoideum, and the mandibula.
② Regio sternocleidomastoidea: The region lying under the musculus sternocleidomastoideus.	
③ Regio cervicalis lateralis (trigonum cervicale posterius): Bounded by the musculus sternocleidomastoideus, musculus trapezius, and clavicula.	Trigonum omoclaviculare: Bounded by the venter inferior musculi omohyoidei, the clavicula, and the musculus sternocleidomastoideus.
	Occipital triangle: Bounded by the venter inferior musculi omohyoidei, the musculus trapezius, and the musculus sternocleidomastoideus.
④ Regio cervicalis posterior (nuchal region): Region lying under the musculus trapezius inferior to its insertion at the linea nuchalis superior and superior to the vertebra prominens (C7).	



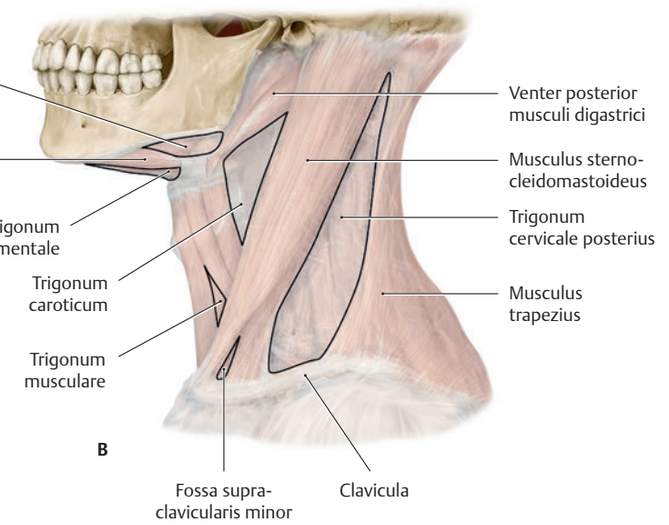
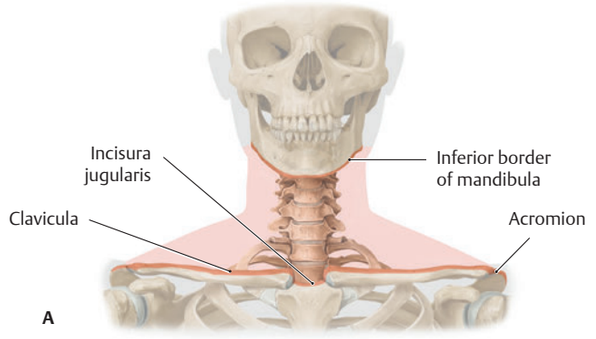


Fig. 12.7 **Muscle dissection of the neck**
A Anterior view with the head slightly extended. **B** Left lateral view.



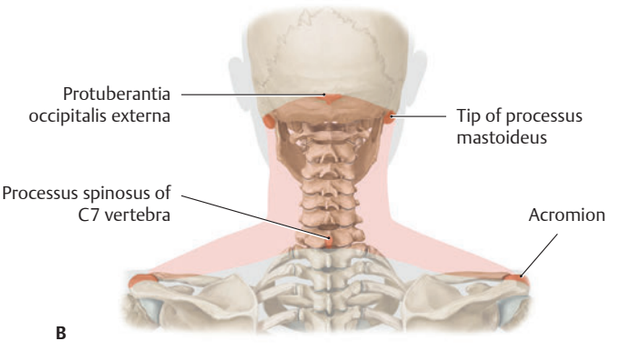


Fig. 12.8 **Palpable bony prominences in the neck**
A Anterior view. **B** Posterior view. Certain palpable structures define the boundaries of the neck. The superior boundaries of the neck are the inferior border of the mandibula, tip of the processus mastoideus, and protuberantia occipitalis externa. The inferior boundaries are the incisura jugularis, clavicula, acromion, and processus spinosus of the C7 vertebra.

Cervical Fasciae

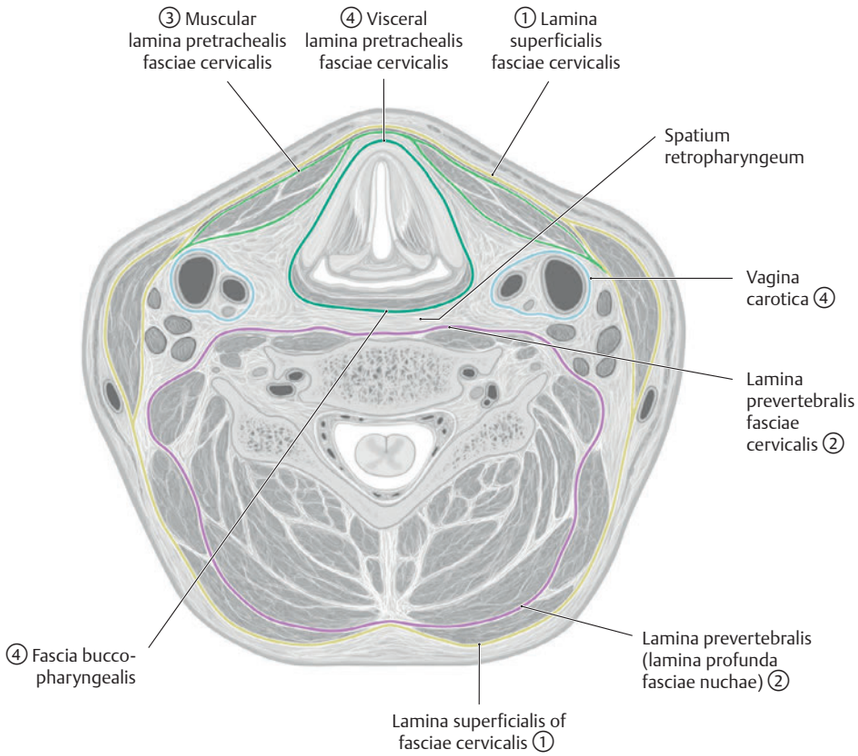


***Fig. 12.9* Cervical fasciae**
The structures of the neck are enclosed by multiple layers of cervical fasciae, sheets of connective tissue that subdivide the neck into compartments. The fascial layers are separated by interfascial spaces. There are four major fascial spaces in the neck: pretracheal, retropharyngeal, prevertebral, and carotid. These spaces are not prominent under normal conditions (the fasciae lie flat against each other). However, the spaces may provide routes for the spread of inflammatory processes (e.g., tonsillar infections in the fossa infratemporalis) from regions of the head and neck into the mediastinum.

***Table 12.5* Cervical fasciae and fascial spaces**

Despite generally being continuous, many of the fascial layers bear different names in different regions of the neck relative to the structures they enclose.

Fascial layer	Description	Contents
Superficial cervical fascia (not shown)	Tela subcutanea that lies deep to the skin and contains the platysma anterolaterally.	Platysma
① Lamina superficialis of fascia cervicalis (yellow) = Fascia cervicalis + lamina superficialis fasciae nuchae	Envelops the entire neck and is continuous with the ligamentum nuchae posteriorly.	Splits around the musculus trapezius and musculus sternocleidomastoideus
② Lamina prevertebralis of fascia cervicalis (purple) = Lamina prevertebralis + lamina profunda fasciae nuchae	Attaches superiorly to the skull base and continues inferiorly into the mediastinum superius, merging with the ligamentum longitudinale anterius. Continues along the arteria subclavia and plexus brachialis, becoming continuous with the axillary sheath. • The lamina prevertebralis splits into an anterior (alar) and a lamina posterior (the “danger space” is located between these layers).	Musculi dorsi proprii and prevertebral muscles
Lamina pretrachealis fasciae cervicalis (green)	③ Muscular portion (light green)	Musculi infrahyoidei
	④ Visceral portion (dark green): Attaches to the cartilago cricoidea and is continuous posteriorly with the fascia buccopharyngealis. Continues inferiorly into the mediastinum superius, eventually merging with the pericardium fibrosum.	Glandula thyroidea, trachea, oesophagus, and pharynx
Vagina carotica (blue). Derived from laminae profunda, prevertebralis, and pretrachealis.	Consisting of loose areolar tissue, the sheath extends from the base of the skull (from the external opening of the canalis caroticus) to the arcus aortae.	Arteriae carotides communis and interna, vena jugularis interna, and nervus vagus (CN X); in addition, CN IX, CN XI, and CN XII briefly pass through the most superior part of the vagina carotica.

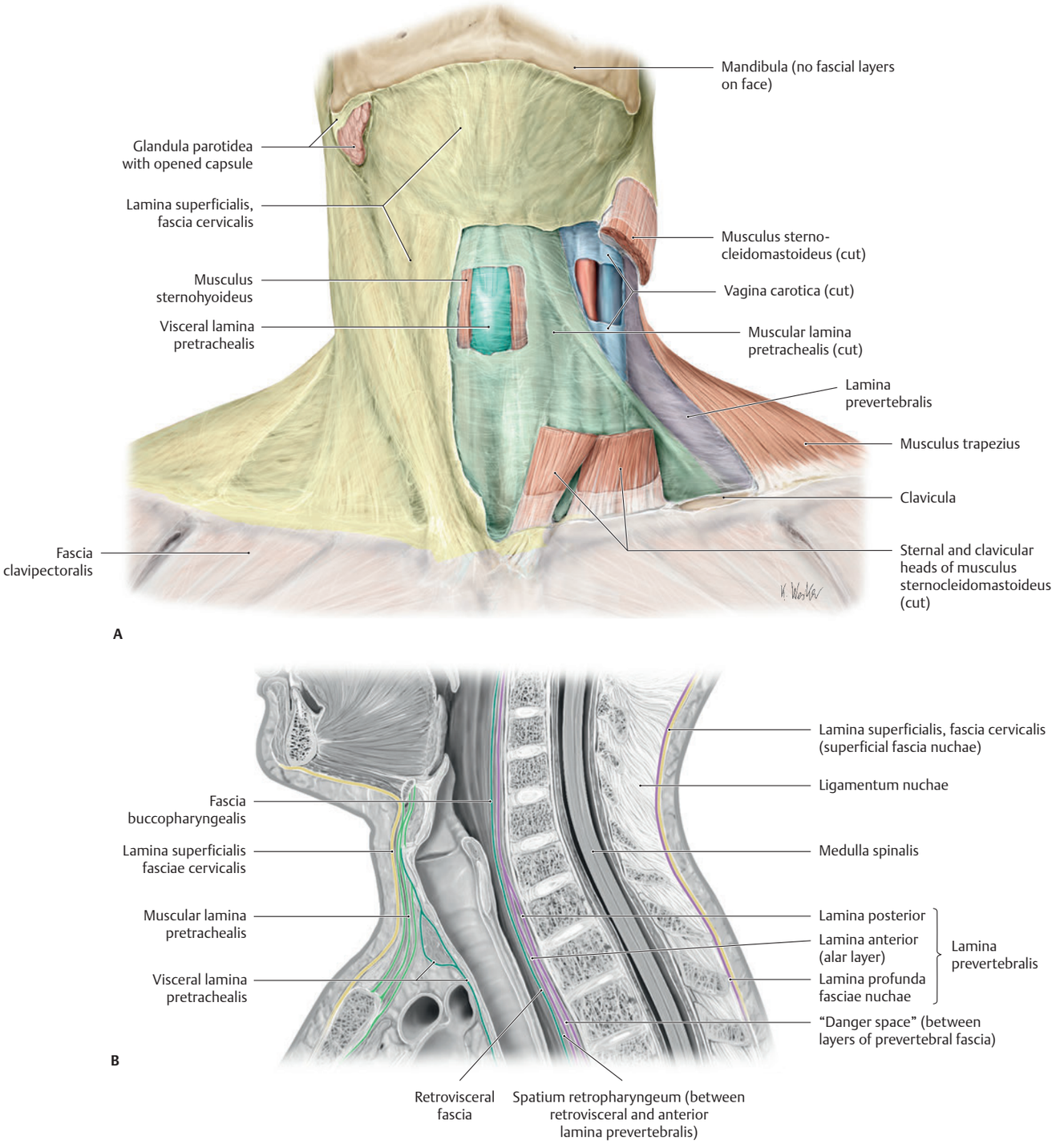


Fig. 12.10 **Fascial relationships in the neck**
A Anterior view with skin, superficial cervical fascia, and platysma removed. **B** Left lateral view of midsagittal section.
The superficial cervical fascia (not shown) lies just deep to the skin and contains the cutaneous muscle of the neck (platysma). The lamina superficialis of the fascia cervicalis contains the remainder of the structures in the neck. The fascia cervicalis attaches to the inferior border of the mandibula and is continuous inferiorly with the fascia clavipectoralis (anteriorly) and the lamina superficialis fasciae nuchae and the fascia thoracolumbalis (posteriorly). The lamina superficialis of the fascia cervicalis splits to enclose the glandula parotidea in a capsule (**A**, swelling of the parotid gland results in pain due to constriction by the capsule). It also splits to enclose the musculi sternocleidomastoideus and trapezius. In the anterior neck, the lamina pretrachealis lies just deep to the lamina superficialis of the fascia cervicalis. It consists of a muscular portion and a visceral portion, which collectively enclose the structures of the anterior neck, including the pharynx, trachea, and oesophagus. The portion of the lamina pretrachealis posterior to the oesophagus is known as the retrovisceral fascia and is a continuation inferiorly of the fascia buccopharyngealis. (**B**). It is separated from the by the spatium retropharyngeum. Inferior to the aditus laryngis, the lamina prevertebralis splits into an anterior (alar) and a lamina posterior, which are separated by the "danger space" — a potential route for the spread of infection from the pharynx into the mediastinum superius. With tuberculous osteomyelitis of the cervical spine, a retropharyngeal abscess may develop in the "danger space" along the lamina prevertebralis. Both prevertebral layers are continuous posteriorly with the deep fascia nuchae. *Note:* The laterally located vagina carotica (**A**) does not appear in the midsagittal section.

Anterior Neck

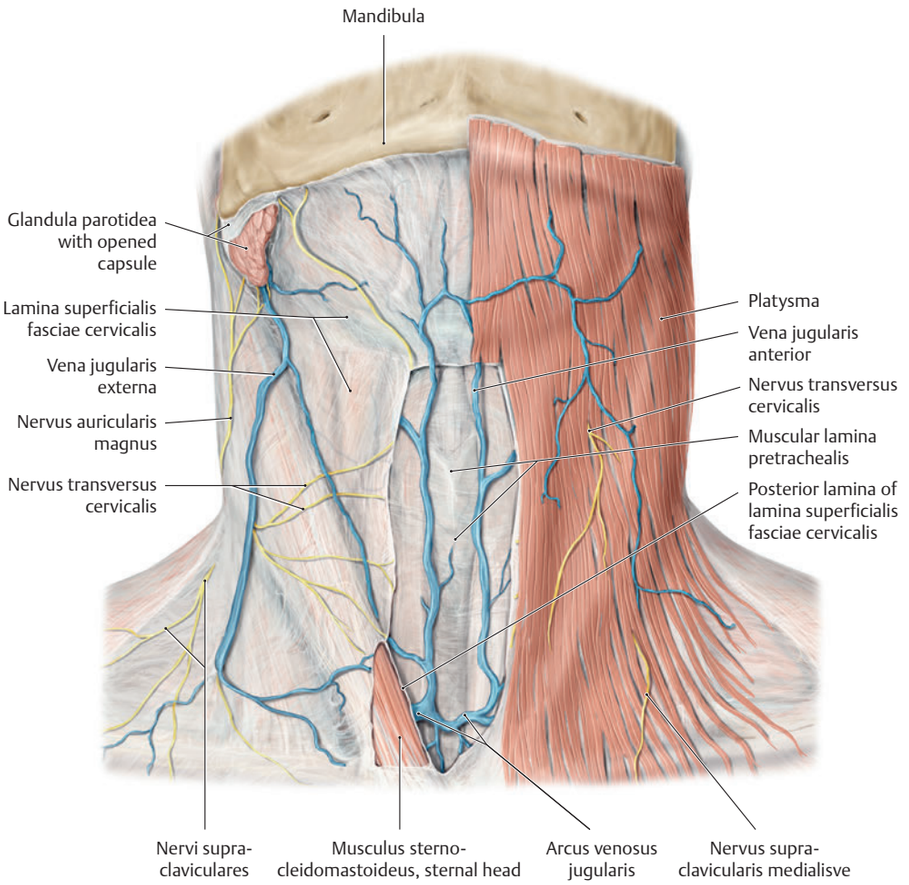


Fig. 12.11 **Anterior neck**
Anterior view. Left neck: Superficial cervical fascia removed to expose platysma. Right neck: Platysma removed to expose the fascia cervicalis. The lamina superficialis of the fascia cervicalis lies just deep to the cutaneous platysma muscle, which is innervated by the ramus cervicalis of the nervus facialis (CN VII). It attaches to the inferior border of the mandibula and is continuous inferiorly with the fascia clavipectoralis. The lamina superficialis splits to form a capsule around the glandula parotidea. Inflammation of the glandula parotidea (e.g., mumps) causes conspicuous facial swelling and deformity in this region ("hamster cheeks" with prominent lobuli auriculae). The lamina superficialis also divides into a deep and a posterior lamina to enclose the musculus sternocleidomastoideus. The lamina superficialis has been cut around the midline to expose the muscular lamina pretrachealis, which encloses the musculi infrahyoidei.

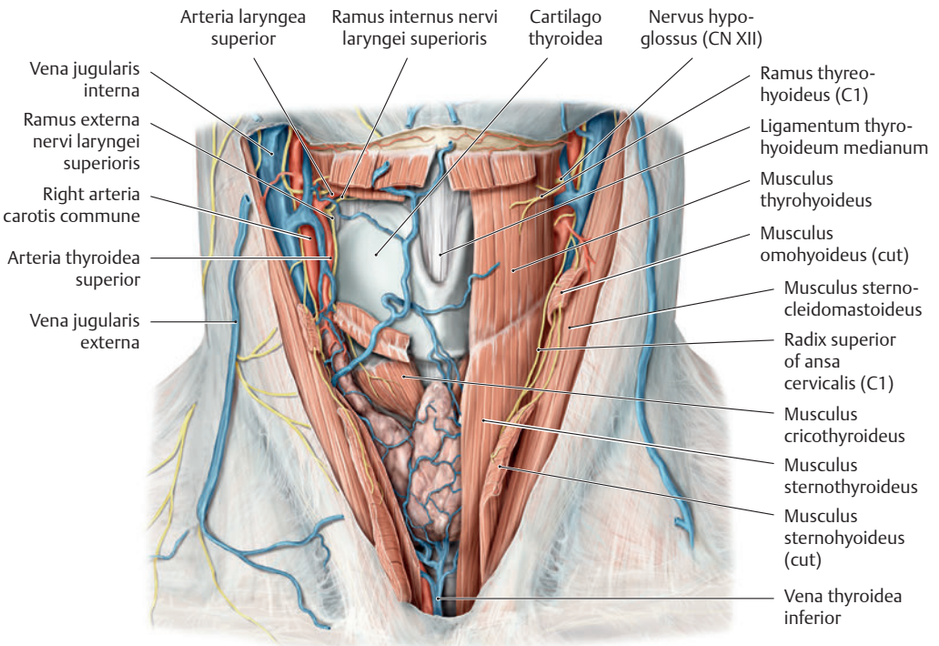


Fig. 12.12 **Trigonum cervicale anterius**
Anterior view. The lamina pretrachealis has been removed to expose the trigonum cervicale anterius, bounded by the mandibula and the anterior borders of the musculi sternocleidomastoidei. The musculi infrahyoidei are enclosed by the muscular lamina pretrachealis (removed). The glandula thyroidea and larynx are enclosed by the visceral lamina pretrachealis (removed). The trigonum cervicale anterius contains neurovasculature of the larynx and glandula thyroidea, including the first branch of the arteria carotis externa (the arteria thyroidea superior). The rami internus and externus (from the nervus laryngeus superior branch of CN X) are visible. C1 motor fibers run with the nervus hypoglossus (CN XII) to the musculi thyrohyoideus and geniohyoideus (not shown). Certain C1 motor fibers leave CN XII to form the radix superior of the ansa cervicalis. The radix inferior is formed by motor fibers from C2 and C3. The ansa cervicalis innervates the musculi omohyoideus, sternothyroideus, and sternohyoideus.

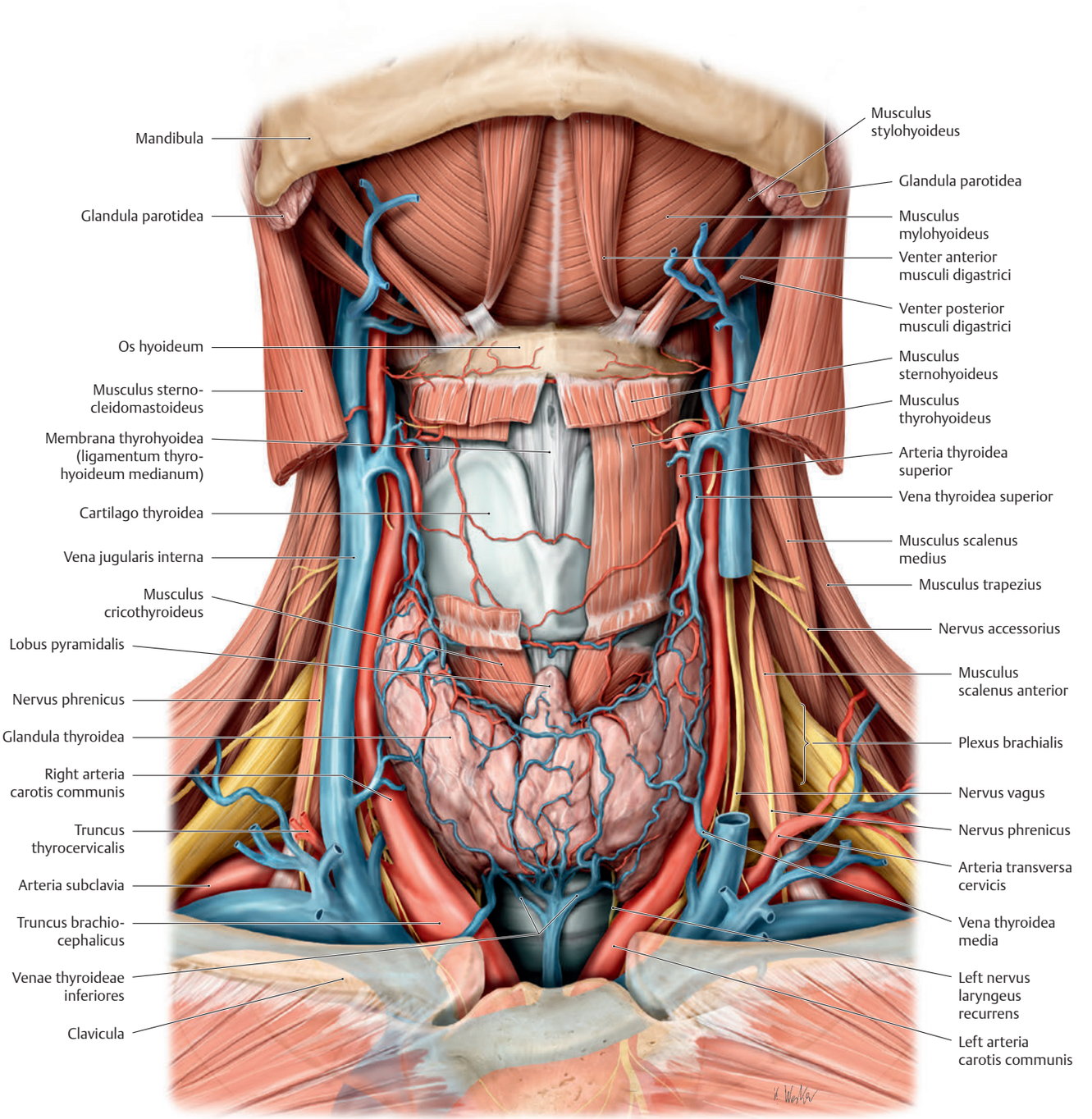
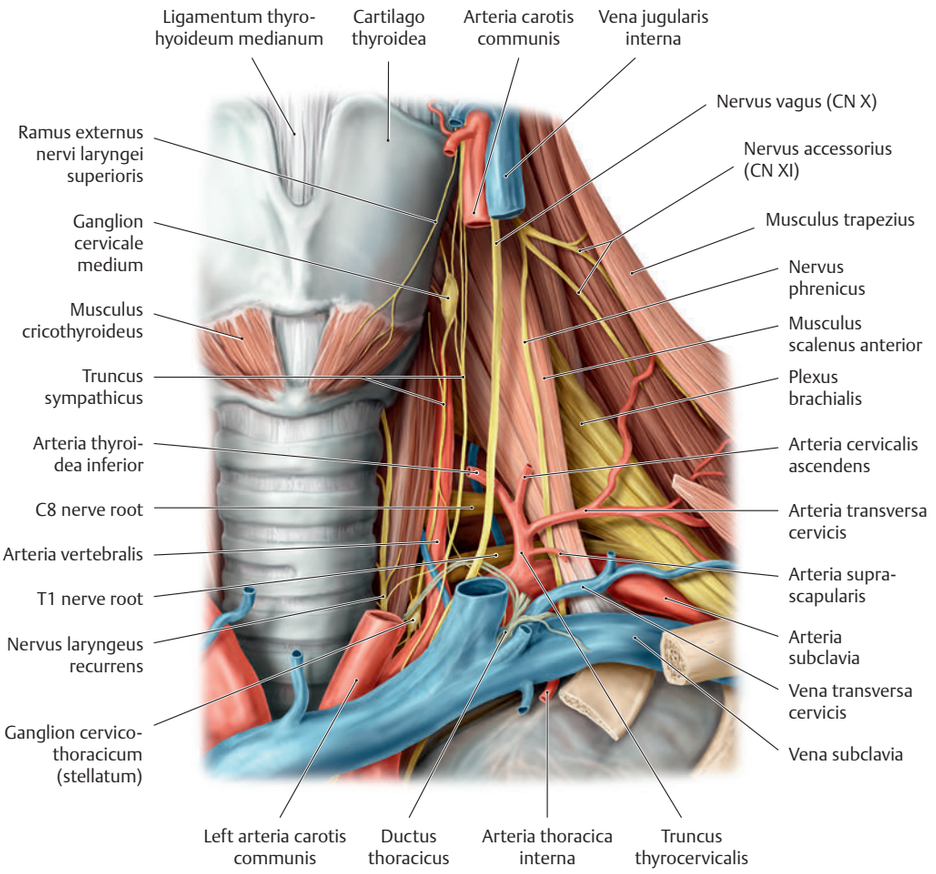


Fig. 12.13 **Root of the neck (apertura thoracis superior)**
Anterior view. The root of the neck contains numerous structures, including the arteria carotis communis, arteria subclavia, vena subclavia, vena jugularis interna, vena thyroidea inferior, nervus vagus, nervus phrenicus, and nervus laryngeus recurrens. A goiter enlarging the inferior pole of the glandula thyroidea can easily compress neurovascular structures at the thoracic inlet.

Root of the Neck

Fig. 12.14 **Root of the neck**
Anterior view of left neck. *Removed:* Clavicula (sternal end), first rib, manubrium sterni, and glandula thyroidea. The left arteria carotis communis has been cut to expose sympathetic ganglia and the ascent of the left nervus laryngeus recurrens nerve from the arcus aortae (where it arises from CN X). The plexus brachialis can be seen emerging from the interscalene space between the musculi scaleni anterior and medius. It courses with the arteria and vena subclavia into the axilla. The nervus phrenicus descends on the musculus scalenus anterior into the mediastinum, where it innervates the diaphragma. The ductus thoracicus terminates at the jugulosubclavian venous junction on the left. It receives lymph from the entire body with the exception of the right upper quadrant, which drains to the ductus lymphaticus dexter.



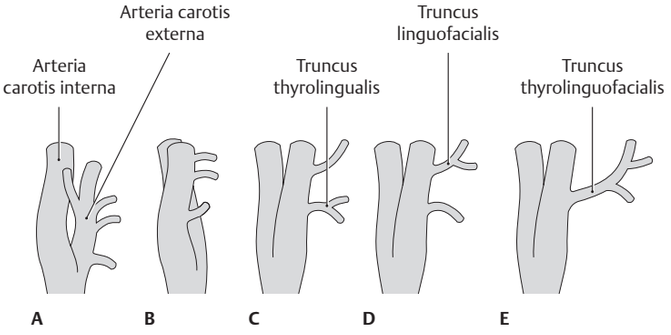


Fig. 12.15 **Variants of the carotid arteries**
(after Faller and Poisel-Golth)
The arteria carotis interna may arise from the arteria carotis communis posterolateral (49%, **A**) or anteromedial (9%, **B**) to the arteria carotis externa, or at other intermediate sites.
The arteria carotis externa may give off a truncus thyrolingualis (4%, **C**), truncus linguofacialis (23%, **D**), or truncus thyrolinguofacialis (0.6%, **E**).

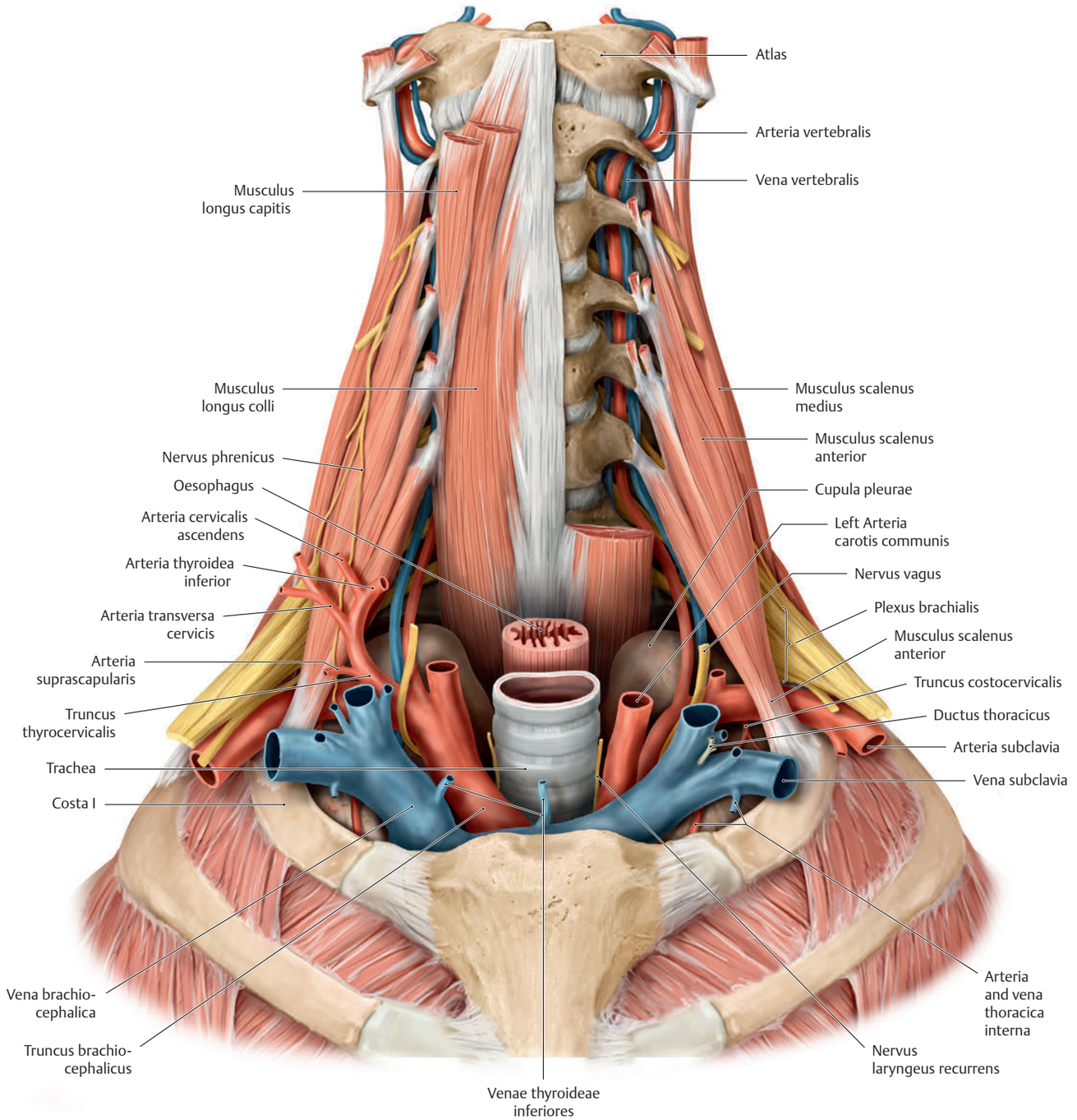


Fig. 12.16 **Deepest Layer of the Neck, Anterior View**
The larynx, glandula thyroidea, trachea, and oesophagus have been removed to expose the prevertebral muscles and columna vertebralis of the neck. The two large vessels (the arteria carotis communis and the vena jugularis interna) have been cut away on both sides, so the deeper lying arteria vertebralis is visible on the left; on the right it is hidden by the prevertebral muscles. The arteria vertebralis runs through the foramina transversaria of the vertebrae cervicales, from C6 upward. It stretches over the arcus posterior atlantis and enters the skull, where contributes to the blood supply to the brain and medulla spinalis. Also visible is the cervical plexus and the nervus phrenicus, the latter extending down over the musculus scalenus anterior to enter the thorax. It then passes anterior to the radix pulmonis and is found sandwiched between the mediastinal pleura and pericardium fibrosum layer of the pericardial sac. The nervus phrenicus supplies motor innervation to the muscle of the diaphragma and receives sensory innervation from the diaphragmatic and mediastinal pleura. Also seen in this dissection are the two bilateral arterial trunks with their branches:

- on the right, the truncus thyrocervicalis is shown with:
  – the arteria thyroidea inferior,
  – the arteria transversa cervicis with rami profundi and superficiales, and
  – the arteria suprascapularis;
  – the arteria cervicalis ascendens
- on the left, the truncus costocervicalis is shown. See **Fig. 12.1** for its branches:
  – the arteria cervicalis profunda, and the arteria intercostalis suprema.

The plexus brachialis and the arteria subclavia emerge from the gap between the musculi scaleni anterior and medius; the vena subclavia passes anterior to the musculus scalenus anterior. The ductus thoracicus enters the junction of the venae jugularis interna and subclavia on the left after draining lymph from three quarters of the body.

Lateral Neck

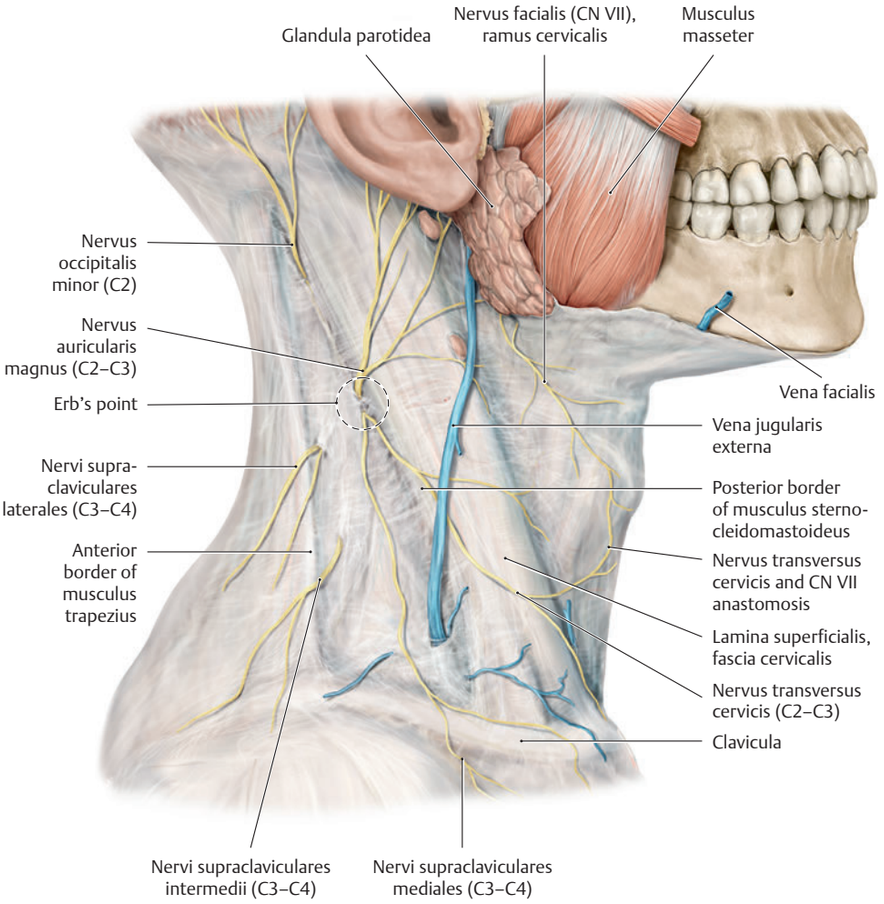


Fig. 12.17 **Lateral neck**
Right lateral view. *Removed:* panniculus adiposus, platysma, and parotid capsule (lamina superficialis fasciae nuchae). The lamina superficialis fasciae nuchae encloses all the structures of the neck with the exception of the platysma. It splits to enclose the glandula parotidea in a capsule. The capsule has been opened to show the emergence of the ramus colli of the nervus facialis (CN VII) from the plexus intraparotideus. The ramus colli provides motor innervation to the platysma. The sensory nerves of the anterolateral neck (nervi occipitalis minor, auricularis magnus, transversus colli, and supraclaviculares) arise from the plexus cervicalis, formed by the anterior rami of C1–C4. They pierce the investing layer at or near Erb's point, midway down the posterior border of the musculus sternocleidomastoideus. *Note:* The nervus transversus colli (sensory) courses deep to the vena jugularis externa and forms a mixed anastomosis with the ramus colli (motor) of CN VII.

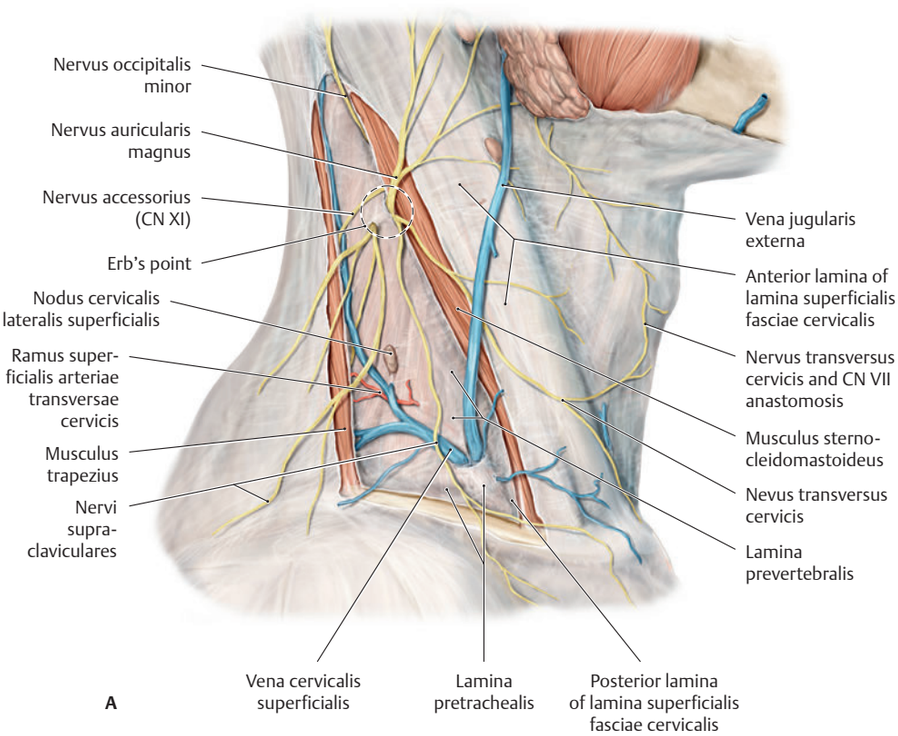
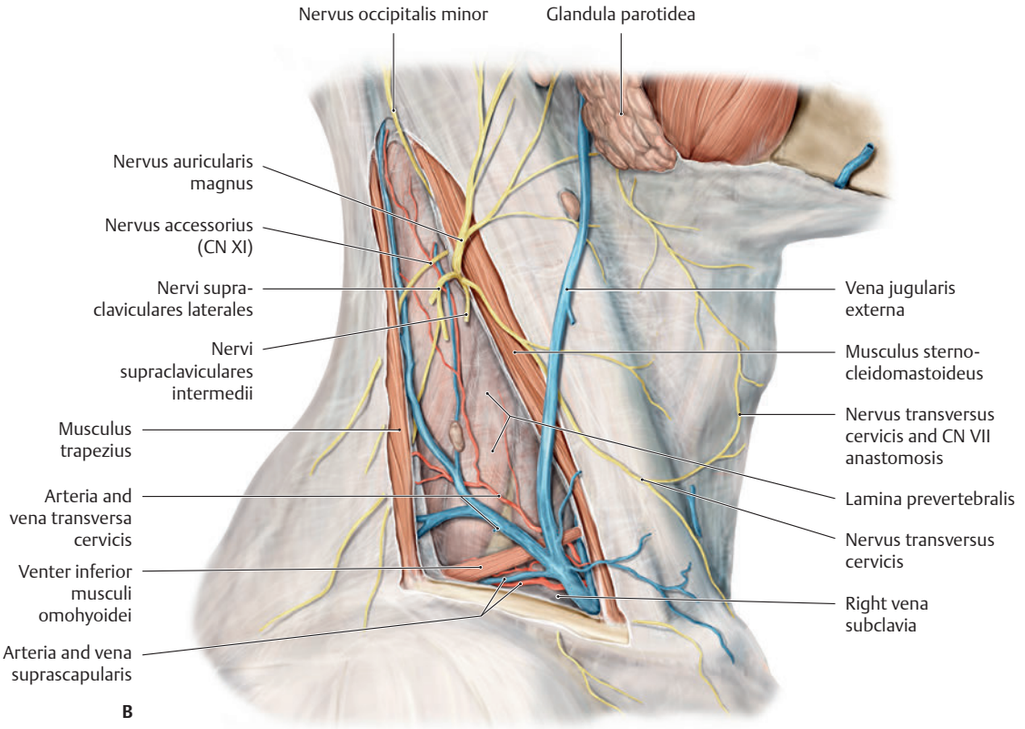
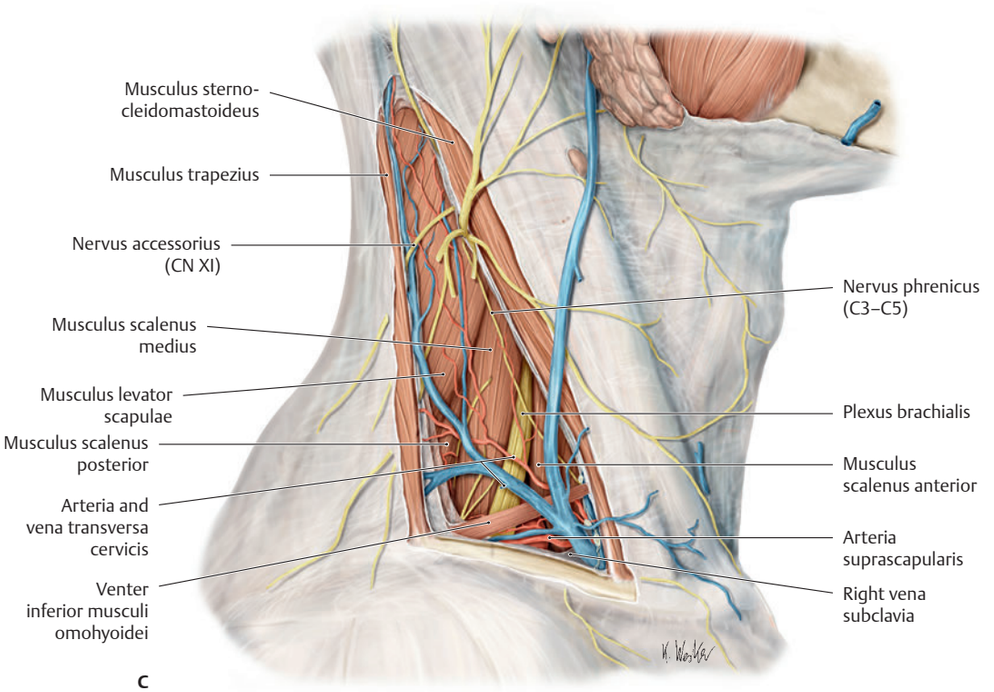


Fig. 12.18 **Trigonum cervicale posterius**
Right lateral view. **A** Lamina superficialis of the fascia cervicalis removed. **B** Lamina pretrachealis removed. **C** Lamina prevertebralis removed.
The lamina superficialis of the fascia cervicalis splits into anterior and posterior lamina to enclose the musculi sternocleidomastoideus and trapezius, both of which are innervated by the nervus accessorius (CN XI). (*Note:* The nervus accessorius may be injured during lymph node biopsy.) Removing the lamina superficialis between the musculi sternocleidomastoideus and trapezius reveals the trigonum cervicale posterius (bounded inferiorly by the clavicula). This exposes the lamina prevertebralis, which encloses the intrinsic and deep muscles of the neck. The lamina prevertebralis is fused to the lamina pretrachealis, which envelops the msuculus omohyoideus (**B**). Removing the lamina prevertebralis exposes the nervus phrenicus (**C**), which arises from the plexus cervicalis and descends to innervate the diaphragma. The plexus brachialis (**C**) is also visible at its point of emergence between the musculi scaleni anterior and medius.


Nervus occipitalis minor
Glandula parotidea
Nervus auricularis magnus
Nervus accessorius (CN XI)
Nervi supra-claviculares laterales
Nervi supraclaviculares intermedii
Musculus trapezius
Arteria and vena transversa cervicis
Venter inferior musculi omohyoidei
Arteria and vena suprascapularis
Vena jugularis externa
Musculus sterno-cleidomastoideus
Nervus transversus cervicis and CN VII anastomosis
Lamina prevertebralis
Nervus transversus cervicis
Right vena subclavia

B


Musculus sterno-cleidomastoideus
Musculus trapezius
Nervus accessorius (CN XI)
Musculus scalenus medius
Musculus levator scapulae
Musculus scalenus posterior
Arteria and vena transversa cervicis
Venter inferior musculi omohyoidei
Nervus phrenicus (C3–C5)
Plexus brachialis
Musculus scalenus anterior
Arteria suprascapularis
Right vena subclavia

C

Deep Lateral Neck

Fig. 12.19 **Trigonum caroticum**
Right lateral view. The lamina superficialis of the deep fascia cervicalis has been removed to expose the trigonum caroticum, a subdivision of the trigonum cervicale anterius bounded by the musculus sternocleidomastoideus, venter superior musculi omohyoidei, and venter posterior musculi digastrici. The laminae prevertebralis and pretrachealis have also been removed to expose the contents of the trigonum caroticum, which include the arteriae carotides interna and externa and the tributaries of the vena jugularis interna. The truncus sympathicus runs between the major blood vessels along with the nervus vagus (CN X). C1 motor fibers course with the nervus hypoglossus (CN XII) to the musculi thyrohyoideus and geniohyoideus. Certain C1 motor fibers leave to form the radix superior of the ansa cervicalis (the radix inferior is formed from C2–C3 fibers). The ansa cervicalis innervates the musculi omohyoideus, sternohyoideus, and sternothyroideus.

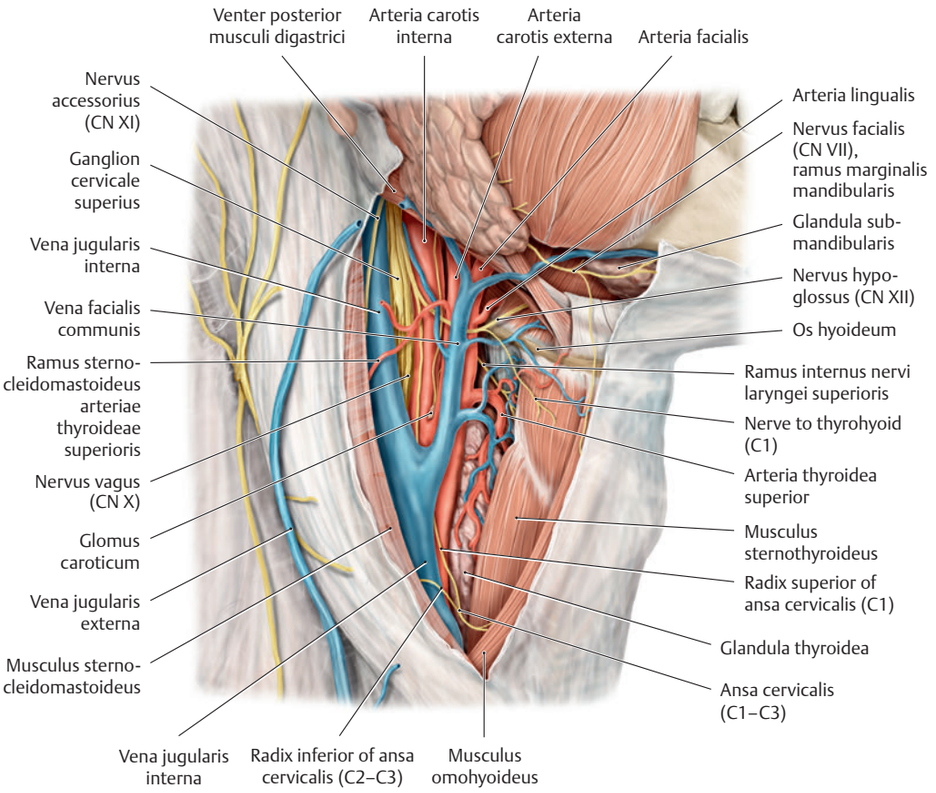
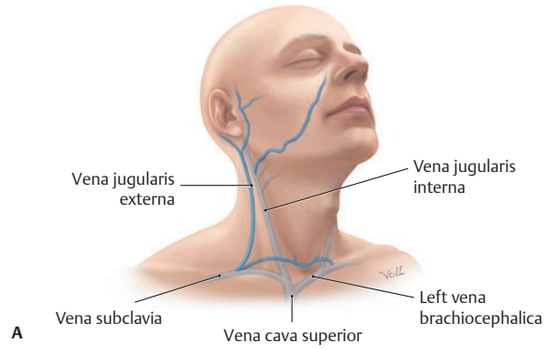
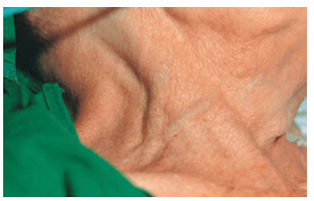


Fig. 12.20 **Impeded blood flow and veins of the neck**
When clinical factors (e.g., chronic lung disease, mediastinal tumors, or infections) impede the flow of blood to the right heart, blood dams up in the vena cava superior and, consequently, the vena jugularis externa (**A**). This causes conspicuous swelling in the vena jugularis externa (and sometimes more minor) veins (**B**).



A



B

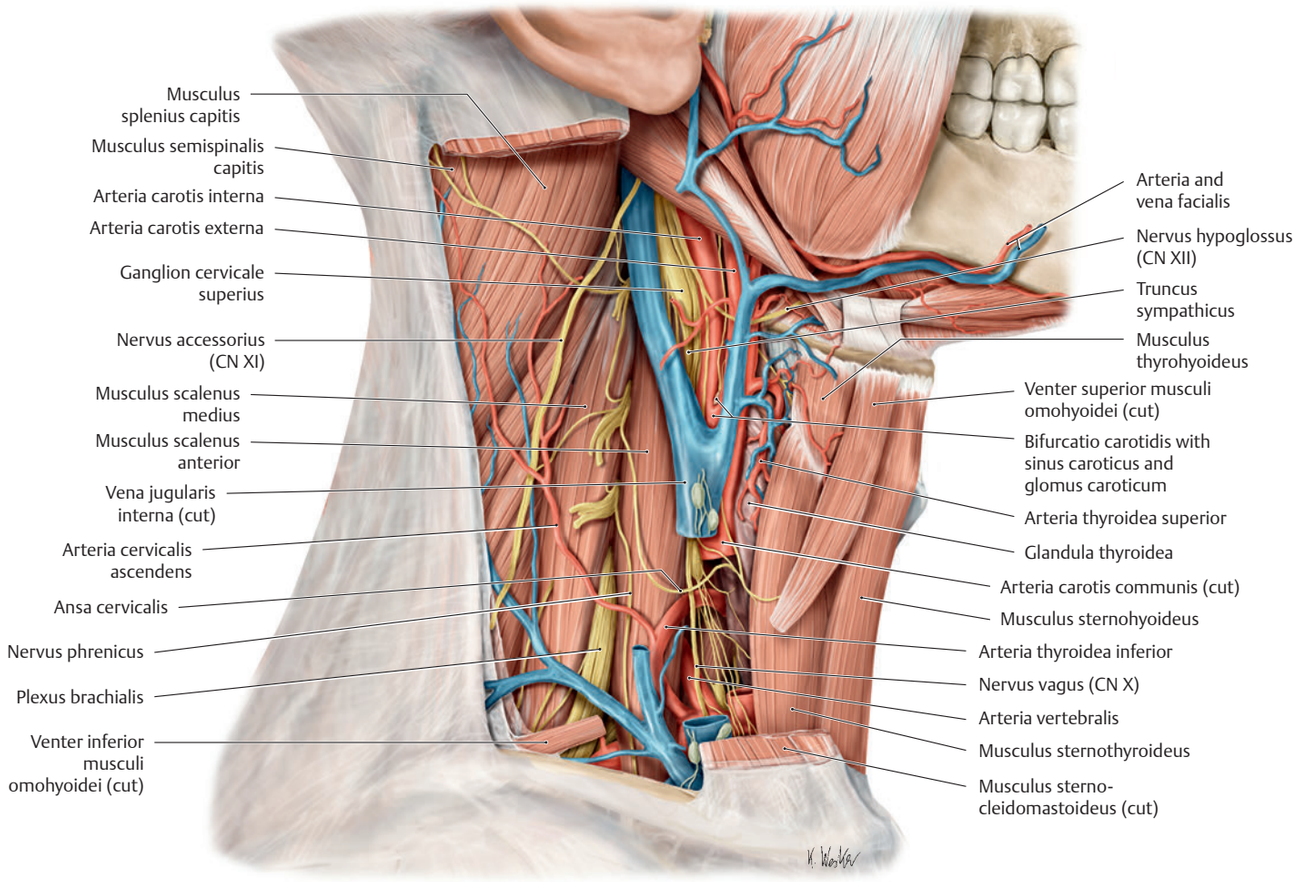


Fig. 12.21 **Deep lateral cervical region**
Right lateral view. The regio sternocleidomastoidea and trigonum caroticum have been dissected along with adjacent portions of the trigona cervicalia posterius and anterius. The vagina carotica has been removed in this dissection along with the fasciae cervicales and musculus omohyoideus to demonstrate important neurovascular structures in the neck:

- Arteria carotis communis with arteriae carotides interna and externa
- Arteriae thyroideae superior and inferior
- Vena jugularis interna
- Nodi cervicales laterales profundi along the vena jugularis interna
- Truncus sympathicus, including ganglia
- Nervus vagus (CN X)
- Nervus accessorius (CN XI)
- Nervus hypoglossus (CN XII)
- Plexus brachialis
- Nervus phrenicus

Massage of the sinus caroticus slows heart rate via the baroreceptor reflex: increased stretch of baroreceptors in the sinus caroticus increases the rate of firing of action potentials in the ramus sinus carotici (a branch of the nervus glossopharyngeus [CN IX]). Impulses are relayed to the vasomotor center in the medulla oblongata, which then decreases sympathetic outflow and increases parasympathetic outflow (via the nervus vagus) to the heart and blood vessels. This results in decreased heart rate, contractility, and cardiac output. It also causes dilation of vessels. This noninvasive technique is useful for termination of supra ventricular tachycardia (SVT).

The nervus phrenicus (C3–C5) originates from the plexus cervicalis and the plexus brachialis. The muscular landmark for locating the nervus phrenicus is the musculus scalenus anterior, along which the nerve descends in the neck. The interscalene triangle is located between the musculi scaleni anterior and medius and the first rib and is traversed by the plexus brachialis and arteria subclavia. The vena subclavia passes anterior to the musculus scalenus anterior.

Damage to the sympathetic chain, for example, due to a tumor at the apex of the lung (“Pancoast” tumor), thyrocervical venous dilation, or trauma, causes disruption of the sympathetic supply to the face. This is known as Horner syndrome and results in ipsilateral miosis (pupillary constriction), enophthalmos (a sunken eye), ptosis (drooping of the upper eyelid), and anhidrosis (loss of sweating) on the affected side.

Posterior Neck

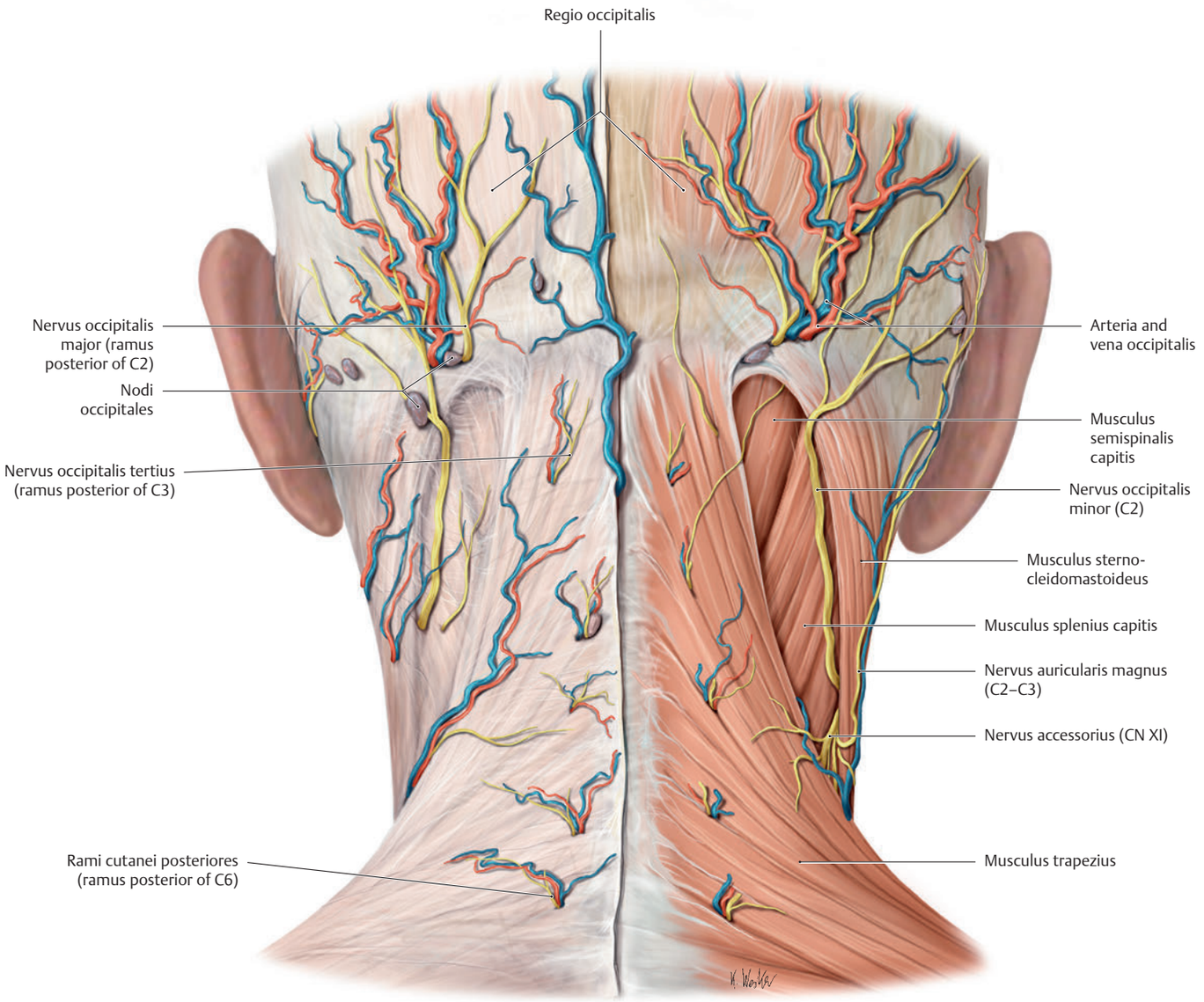


Fig. 12.22 **Regio cervicalis posterior**
Posterior view. Left side: Lamina superficialis fasciae nuchae. Right side: All fascia removed (superficial cervical fascia, lamina superficialis fasciae cervicalis, lamina prevertebralis).
The regio cervicalis posterior is bounded superiorly by the linea nuchalis superior (the attachment of the musculi trapezius and sternocleidomastoideus to the os occipitale) and inferiorly by the palpable processus spinosus of the last cervical vertebra, the vertebra prominens (C7). The regio cervicalis posterior, like the rest of the neck, is completely enveloped in superficial fascia nuchae (left side). The lamina superficialis fasciae cervicalis envelops the musculus trapezius and splits to enclose the musculus sternocleidomastoideus. Both muscles are innervated by the nervus accessorius (CN XI). The deep fascia nuchae (the posterior continuation of the lamina prevertebralis) lies deep to the musculi trapezius and sternocleidomastoideus and encloses the musculi dorsi proprii (here: musculi semispinalis and splenius capitis). The musculi dorsi proprii receive motor and sensory innervation from the rami posteriores of the nervi spinales (see **Fig. 12.25**). The nervi auricularis magnus and occipitalis minor are also visible in this dissection. They are sensory nerves arising from the plexus cervicalis (formed by the rami anteriores of C1–C4). The major artery of the occipital region is the arteria occipitalis, a posterior branch of the arteria carotis externa.

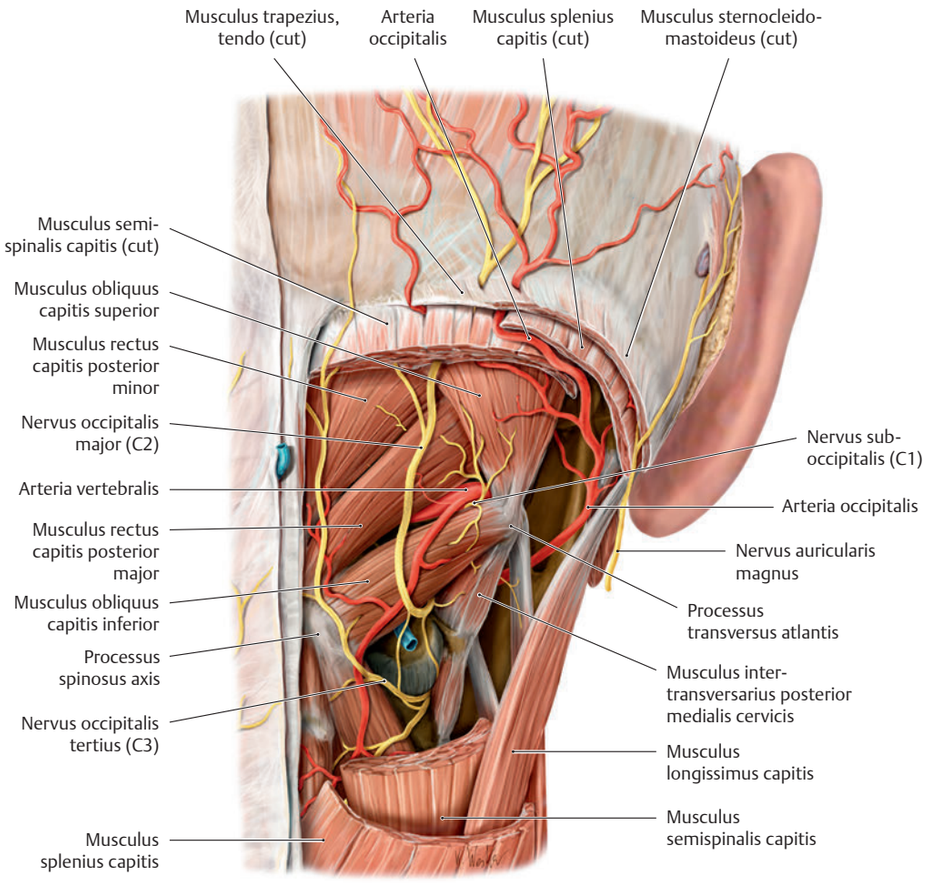


Fig. 12.23 **Suboccipital triangle**
Posterior view of right side. The suboccipital triangle is a muscular triangle lying deep to the musculi trapezius, splenius capitis, and semispinalis capitis. It is bounded superiorly by the musculus rectus capitis posterior major, laterally by the musculus obliquus capitis superior, and inferiorly by the musculus obliquus capitis inferior. A short segment of the arteria vertebralis runs through the deep part of the triangle after leaving the foramen transversarium of the atlas. It gives off branches to the surrounding short nuchal muscles before exiting the suboccipital triangle by perforating the membrana atlanto-occipitalis posterior. The arteriae vertebrales unite intracranially to form the arteria basilaris, a major contributor to cerebral blood flow.

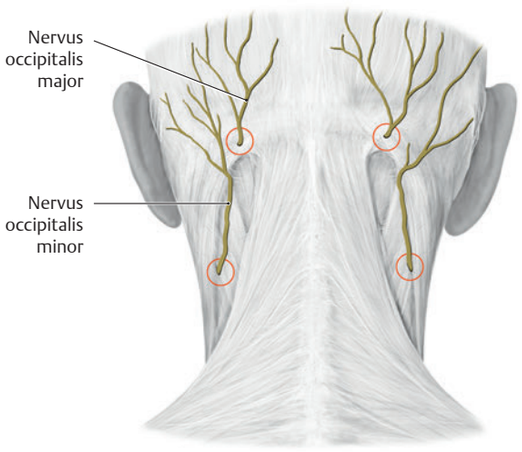


Fig. 12.24 **Sites of emergence of the nervi occipitales**
Posterior view. The sites where the nervi occipitales minor and major emerge from the fascia into the subcutaneous connective tissue are clinically important because they are tender to palpation in certain diseases (e. g., meningitis). The examiner tests the sensation of these nerves by pressing lightly on the circled points with the thumb. If these points (but not their surroundings) are painful, the clinician should suspect meningitis.

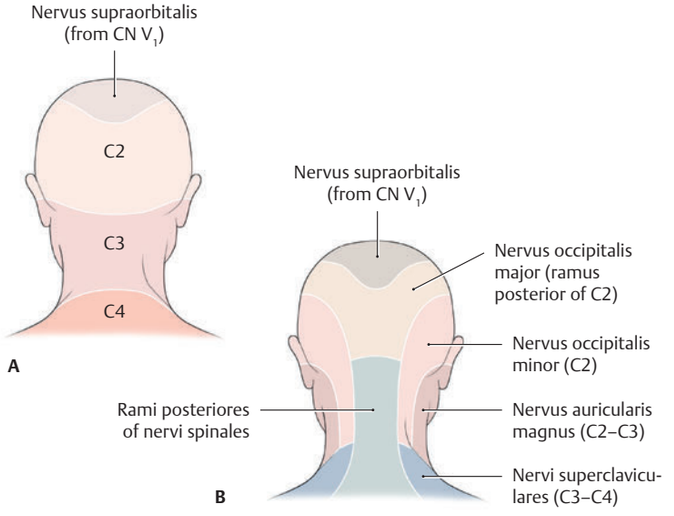


Fig. 12.25 **Cutaneous innervation of the posterior neck**
Posterior view. **A** Segmental innervation (dermatomes). **B** Peripheral cutaneous nerves.
The occiput and nuchal regions derive most of their segmental innervation from the C2 and C3 nervi spinales. Of the specific cutaneous nerves, the nervus occipitalis major is a branch of the ramus posterior of C2; the nervi occipitalis minor, auricularis magnus, and supraclavicularis are branches of the plexus cervicalis (formed from the rami anteriores of C1–C4).

Spatium Peripharyngeum (I)

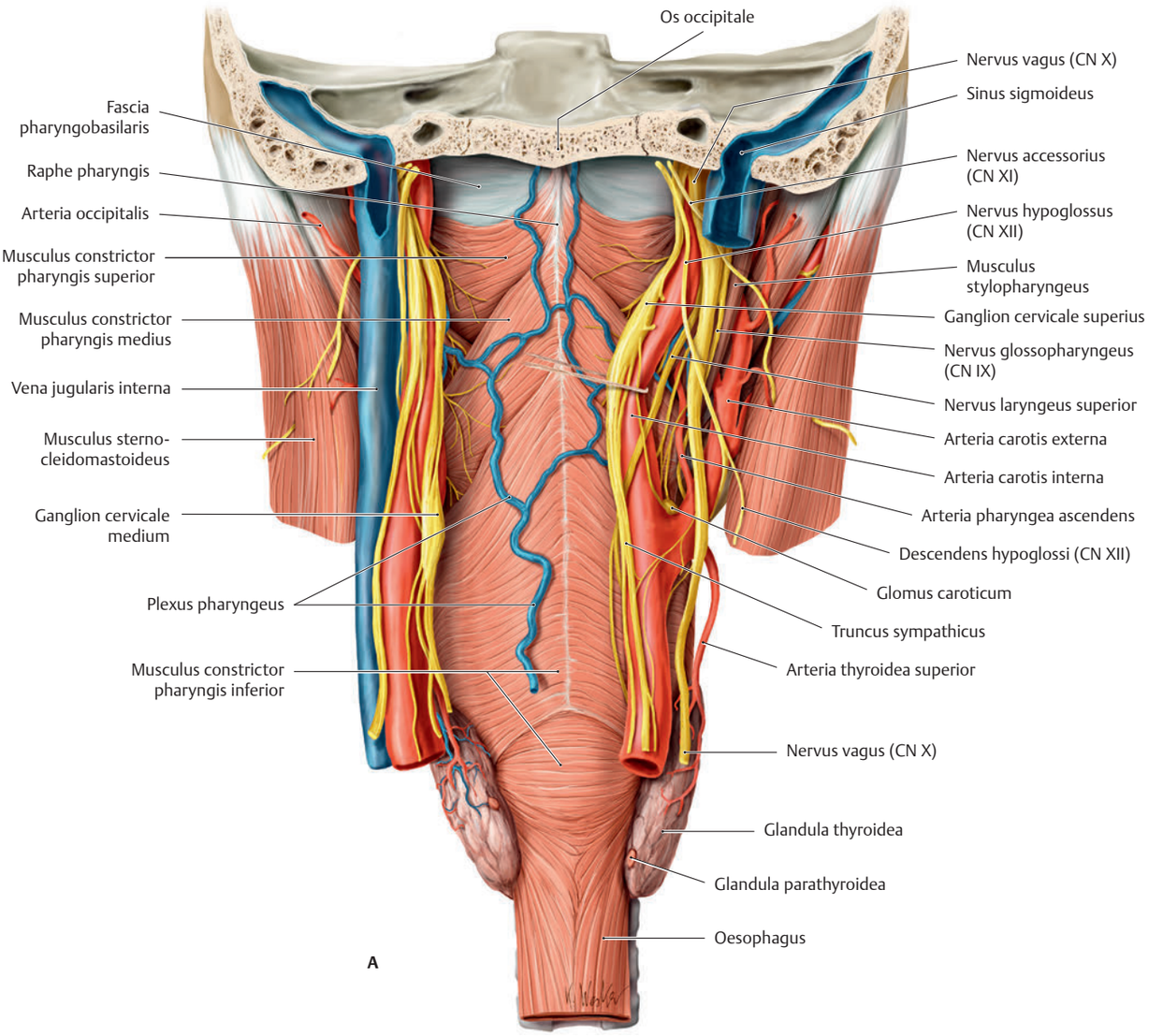


Fig. 12.26 **Spatium peripharyngeum**
Posterior view. **A** *Removed:* Fascial layers. **B** Pharynx opened along raphe pharyngis. The arteriae carotides communis and interna travel with the vena jugularis and nervus vagus within the vagina carotica, which attaches to the skull base.

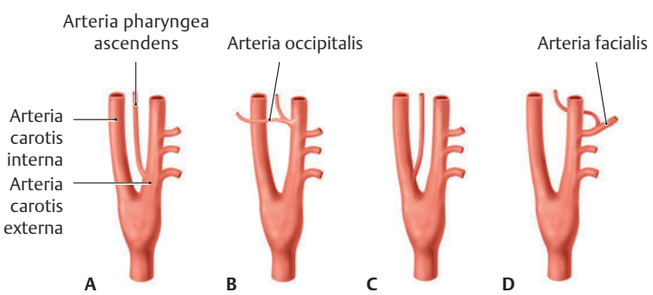
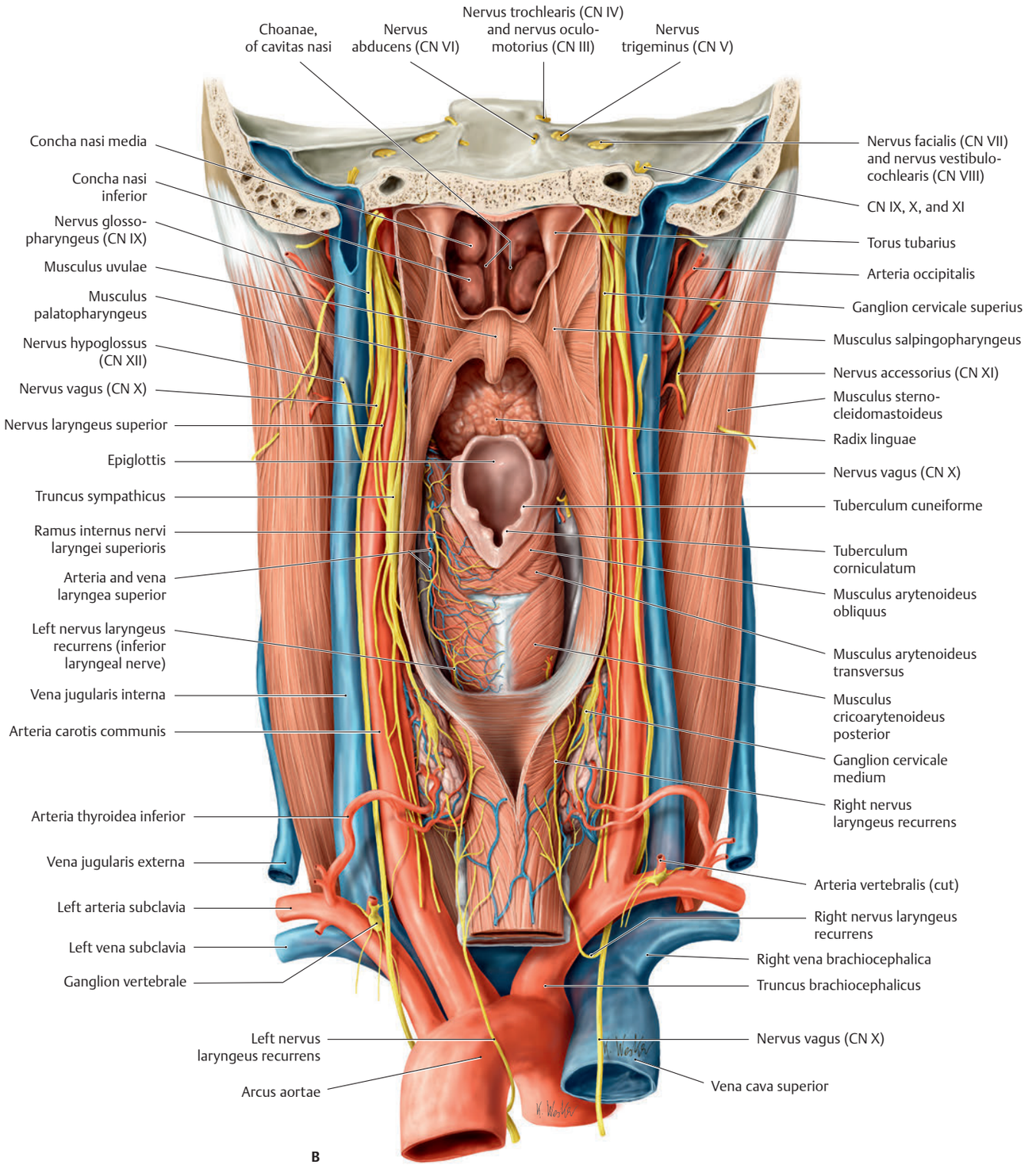


Fig. 12.27 **Arteria pharyngea ascendens: variants**
(after Tillmann, Lippert, and Pabst)
Left lateral view. The main arterial vessel supplying the upper and middle pharynx is the arteria pharyngea ascendens. In 70% of cases (**A**) it arises from the posteroinferior surface of the arteria carotis externa. In approximately 20% of cases it arises from the arteria occipitalis (**B**). Occasionally (8%) it originates from the arteria carotis interna or bifurcatio carotidis (**C**), and in 2% of cases it arises from the arteria facialis (**D**).


Choanae, of cavitas nasi
Nervus abducens (CN VI)
Nervus trochlearis (CN IV) and nervus oculo-motorius (CN III)
Nervus trigeminus (CN V)
Concha nasi media
Concha nasi inferior
Nervus glosso-pharyngeus (CN IX)
Musculus uvulae
Musculus palatopharyngeus
Nervus hypoglossus (CN XII)
Nervus vagus (CN X)
Nervus laryngeus superior
Epiglottis
Truncus sympathicus
Ramus internus nervi laryngei superioris
Arteria and vena laryngea superior
Left nervus laryngeus recurrens (inferior laryngeal nerve)
Vena jugularis interna
Arteria carotis communis
Arteria thyroidea inferior
Vena jugularis externa
Left arteria subclavia
Left vena subclavia
Ganglion vertebrale
Left nervus laryngeus recurrens
Arcus aortae
Nervus facialis (CN VII) and nervus vestibulo-cochlearis (CN VIII)
CN IX, X, and XI
Torus tubarius
Arteria occipitalis
Ganglion cervicale superius
Musculus salpingopharyngeus
Nervus accessorius (CN XI)
Musculus sterno-cleidomastoideus
Radix linguae
Nervus vagus (CN X)
Tuberculum cuneiforme
Tuberculum corniculatum
Musculus arytenoideus obliquus
Musculus arytenoideus transversus
Musculus cricoarytenoideus posterior
Ganglion cervicale medium
Right nervus laryngeus recurrens
Arteria vertebralis (cut)
Right nervus laryngeus recurrens
Right vena brachiocephalica
Truncus brachiocephalicus
Nervus vagus (CN X)
Vena cava superior
B

Spatium Peripharyngeum (II)

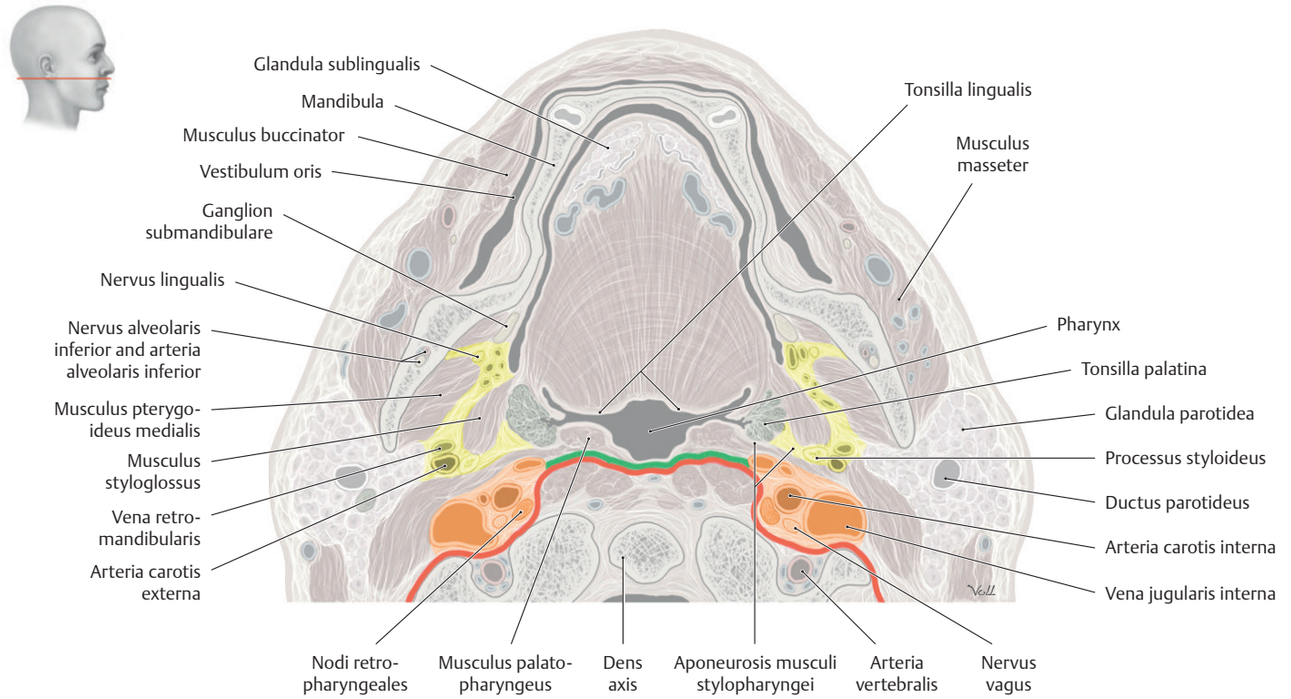


Fig. 12.28 **Spaces in the neck**
Transverse section, superior view. The pharynx, larynx, and glandula thyroidea are enclosed by the lamina pretrachealis fasciae cervicalis. The posterior portion of the lamina pretrachealis that is in direct contact with the pharynx is called the fascia buccopharyngealis. The fascial space surrounding the pharynx (spatium peripharyngeum) is divided into a posterior space (spatium retropharyngeum) and a lateral space (spatium parapharyngeum). The retropharyngeal (green) lies between the anterior (alar) layer of the lamina prevertebralis (red) and the fascia buccopharyngealis, the posterior portion of the lamina pretrachealis. The spatium parapharyngeum is divided by the aponeurosis musculi stylopharyngei into an anterior and a posterior part. The anterior part (yellow) is contained within the lamina pretrachealis in the neck (this section is through the cavitas oris). The posterior part (orange) is contained within the vagina carotica.

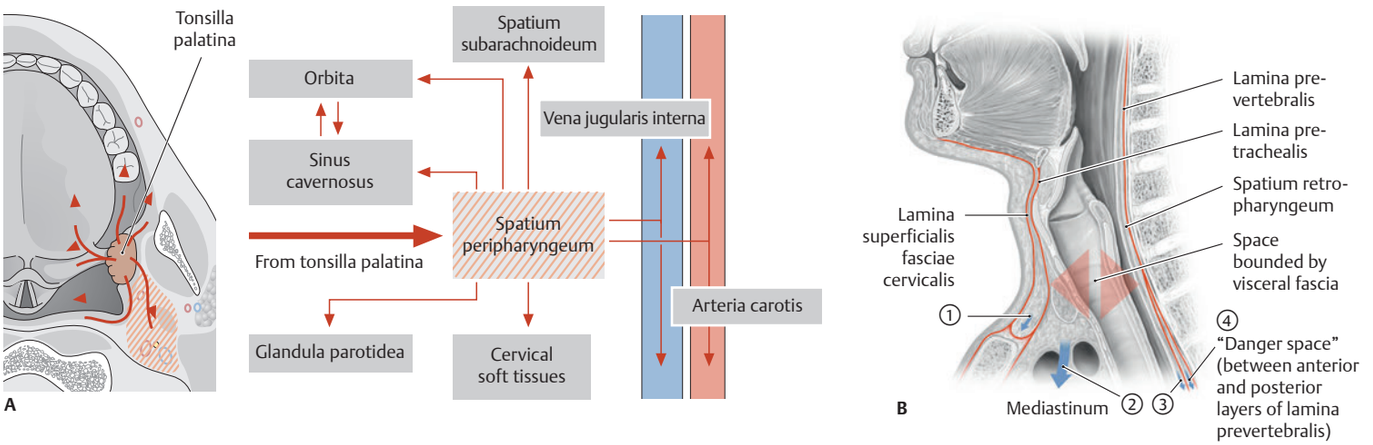


Fig. 12.29 **Role of the spatium peripharyngeum in the spread of infection** (after Becker, Naumann, and Pfaltz)
Bacteria and inflammatory processes from the cavitates oris and nasi (e.g., tonsillitis, dental infections) may invade the spatium peripharyngeum. From there, they may spread in various directions (**A**). Invasion of the vena jugularis interna may lead to bacteremia and sepsis. Invasion of the spatium subarachnoideum poses a risk of meningitis. Inflammatory processes may also track downward into the mediastinum (gravitation abscess), causing mediastinitis (**B**). These may spread anteriorly in the spaces between the lamina superficialis of the fascia cervicalis and muscular lamina pretrachealis ① or in the space within the lamina pretrachealis ②. They may also spread posteriorly in the spatium retropharyngeum ③ between the anterior fascia buccopharyngealis and the (alar) layer of the lamina prevertebralis. Infections that enter the "danger space" ④ between the anterior and posterior layers of the lamina prevertebralis may spread directly into the mediastinum.

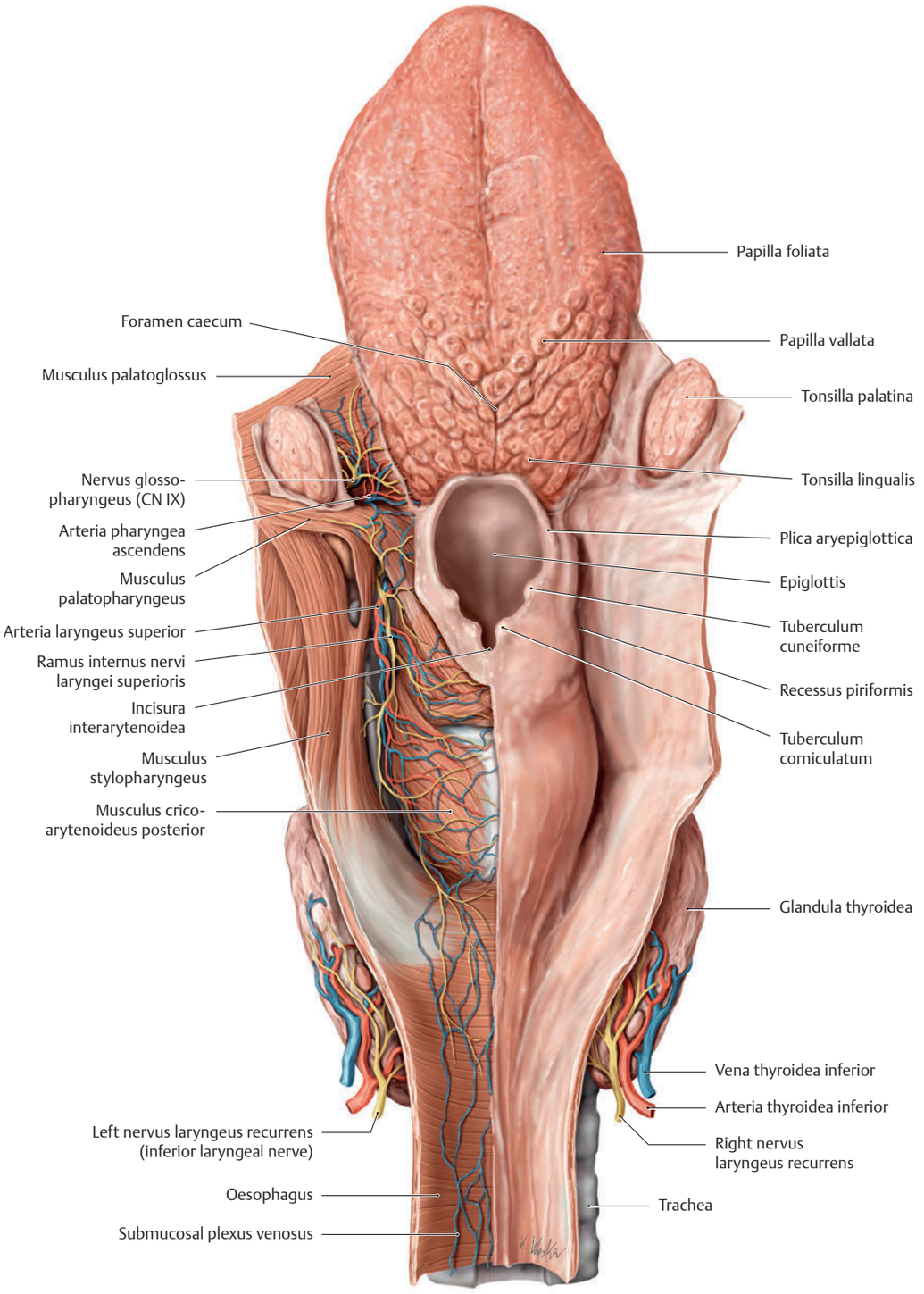


Fig. 12.30 **Neurovascular structures of the spatium peripharyngeum**

Posterior view of an en bloc specimen composed of the tongue, larynx, oesophagus, and glandula thyroidea, as it would be resected at autopsy for pathologic evaluation of the neck. This dissection clearly demonstrates the branching pattern of the neurovascular structures that occupy the plane between the pharyngeal muscles.

Note the vascular supply to the tonsilla palatina and its proximity to the neurovascular bundle, which creates a risk of hemorrhage during tonsillectomy.

Larynx

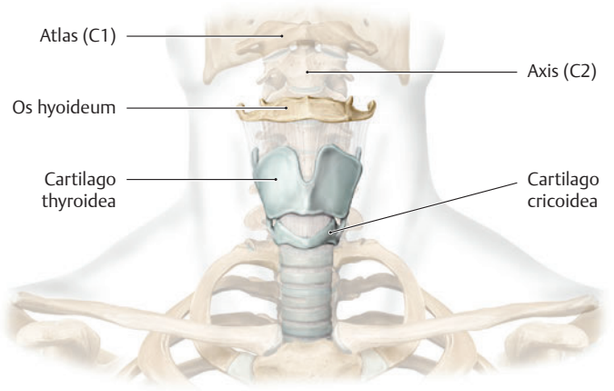


Fig. 13.1 **Location of the larynx**
Anterior view. The bony structures of the neck have characteristic vertebral levels (shown for upright adult male):

- Os hyoideum: C3
- Cartilago thyroidea (superior border): C4
- Laryngotracheal junction: C6–C7

These structures are a half vertebra higher in women and children. The cartilago thyroidea is especially prominent in males, forming the prominentia laryngea ("Adam's apple").

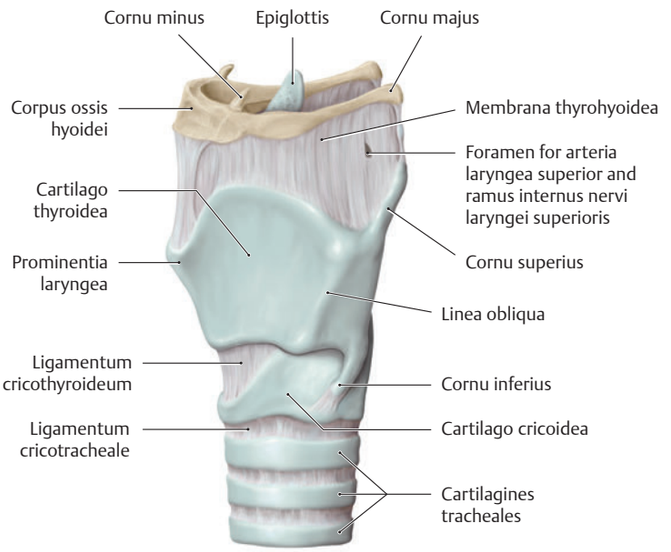


Fig. 13.2 **Larynx: Overview**
Oblique left anterolateral view. The larynx consists of five cartilages: two external cartilages (thyroidea and cricoidea) and three internal cartilages (epiglottica, arytenoidea, and corniculata). Elastic ligaments connect these cartilages to each other as well as to the trachea and os hyoideum. This allows laryngeal motion during swallowing. The cartilagines thyroidea, cricoidea, and arytenoidea are hyaline, and the epiglottis and cartilago corniculata are elastic fibrocartilage.

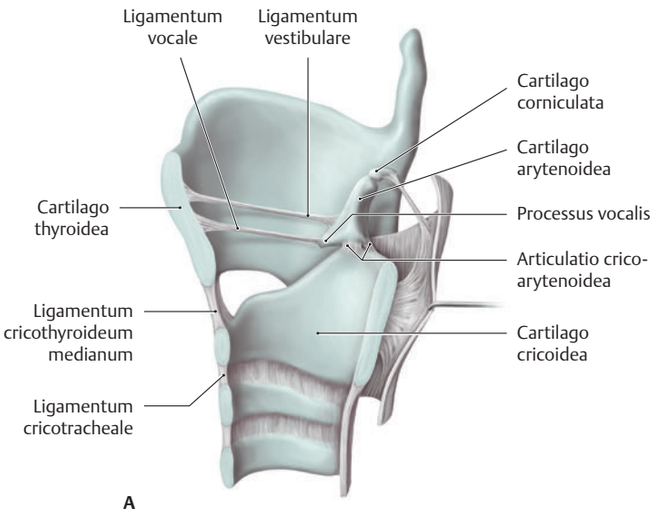


Fig. 13.3 **Laryngeal cartilages and ligaments**
A Left medial view of sagittal section. **B** Posterior view. Arrows indicate movement in the various joints.
The large cartilago thyroidea encloses most of the other cartilages. It articulates with the cartilago cricoidea inferiorly at the paired articulationes cricothyroideae, allowing it to tilt relative to the cartilago cricoidea. The cartilagines arytenoideae move during phonation: their bases can translate or rotate relative to the cartilago cricoidea at the articulatio cricoarytenoidea.

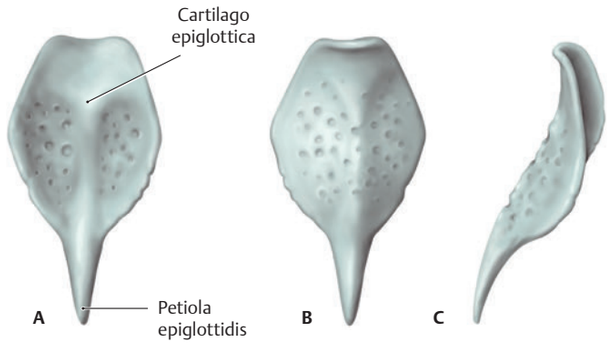


Fig. 13.4 **Cartilago epiglottica**
A Laryngeal (posteroinferior) view. **B** Lingual (anterosuperior) view. **C** Left lateral view.
The elastic cartilago epiglottica regulates the entrance of material into the larynx. During breathing, it is angled posterosuperiorly, allowing air to enter the larynx and trachea. During swallowing, the larynx is elevated relative to the os hyoideum. The epiglottis assumes a more horizontal position, preventing food from entering the airway.

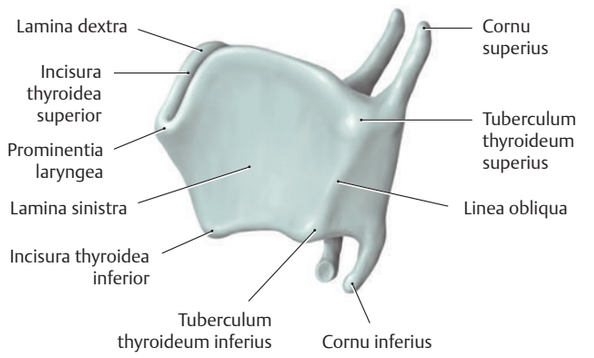


Fig. 13.5 **Cartilago thyroidea**
Oblique left lateral view. The hyaline cartilago thyroidea consists of two quadrilateral plates (laminae) that are joined at the anterior midline. The superior portion of this junction is the prominentia laryngea ("Adam's apple"). The posterior ends of the laminae are prolonged forming the cornua superiora and inferiora, which serve as anchors for ligaments.

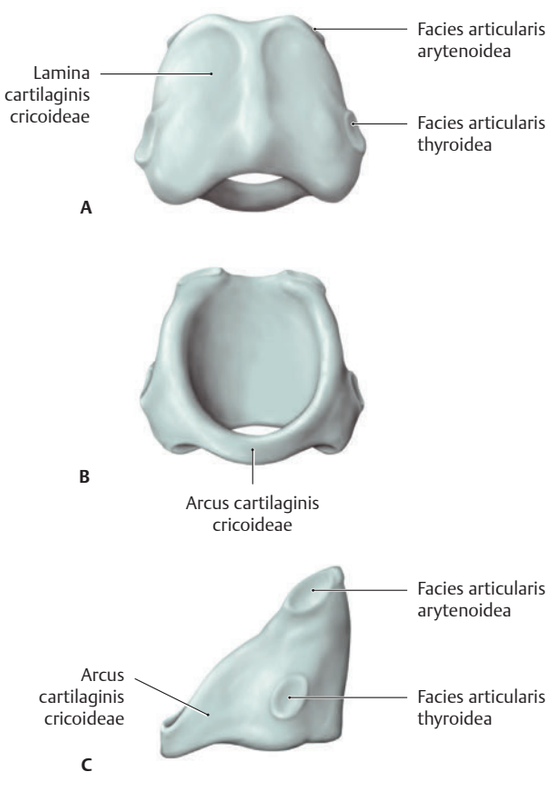


Fig. 13.6 **Cartilago cricoidea**
A Posterior view. **B** Anterior view. **C** Left lateral view. The hyaline cartilago cricoidea is a ring that is connected inferiorly to the highest cartilago trachealis by the ligamentum cricotracheale. The cricoid ring is expanded posteriorly to form a lamina. The laminae each have an upper and lower articular facet for the cartilago arytenoidea (facies articularis arytenoidea) and thyroidea (facies articularis thyroidea), respectively.

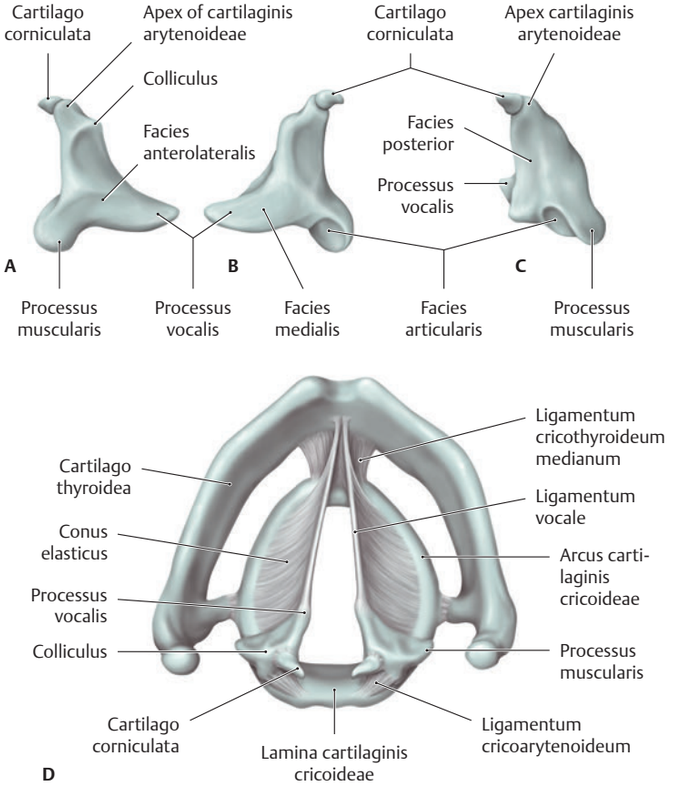


Fig. 13.7 **Cartilagines arytenoideae and corniculatae**
Right cartilagines. **A** Right lateral view. **B** Left lateral (medial) view. **C** Posterior view. **D** Superior view.
The cartilagines arytenoideae alter the positions of the vocal cords during phonation. The pyramid-shaped hyaline cartilages have three facies (anterolateralis, articularis, medialis, and posterior), an apex, and a basis with processus vocalis and muscularis. The apex articulates with the tiny cartilagines corniculatae, which are composed of elastic fibrocartilage.

Musculi Laryngis

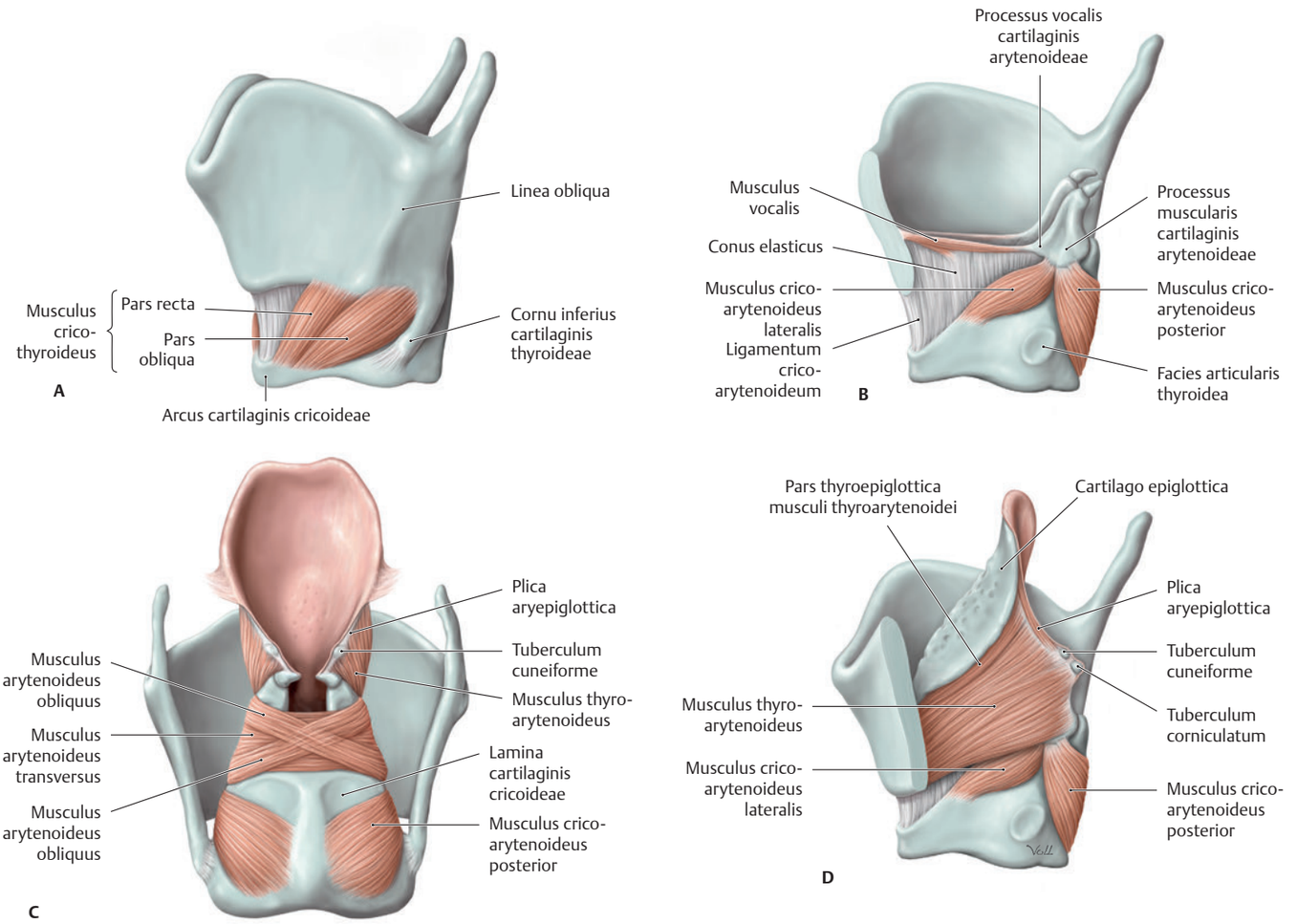


Table 13.1 Laryngeal muscles

The musculi laryngis move the cartilagines laryngis relative to one another and affect the tension and/or position of the plicae vocales. Numerous muscles move the larynx as a whole (musculi infrahyoidei, suprahyoidei, constrictores pharyngis, stylopharyngeus, etc.).

Muscle	Innervation	Action	Plicae vocales	Rima glottidis
Musculus cricoarytenoideus posterior	Nervus laryngeus recurrens**	Rotates cartilago arytenoidea outward and slightly to the side	Abducts	Opens
Musculus cricoarytenoideus lateralis*		Rotates cartilago arytenoidea inward	Adducts	Closes
Musculus arytenoideus transversus		Moves cartilagines arytenoideae toward each other		
Musculus thyroarytenoideus		Rotates cartilago arytenoidea inward	Relaxes	Closes
Musculus vocalis***		Regulates tension of plicae vocales	Relaxes	None
Musculus cricothyroideus	Ramus externus nervi laryngei superioris	Tilts cartilago cricoidea forward, acting on the vocalis muscle to increase tension in the plicae vocales	Lengthens	

*The musculus cricoarytenoideus lateralis is called the muscle of phonation as it initiates speech production.

**Unilateral loss of the nervus laryngeus recurrens (e.g., due to nodal metastases from a hilar bronchial carcinoma of the left lung) leads to ipsilateral palsy of the musculus cricoarytenoideus posterior. This prevents complete abduction of the plicae vocales, causing hoarseness. Bilateral nerve loss (e.g., due to thyroid surgery) may cause asphyxiation.

***The musculus vocalis is derived from the inferior fibers of the musculus thyroarytenoideus. These fibers connect the cartilago arytenoidea with the ligamentum vocale.

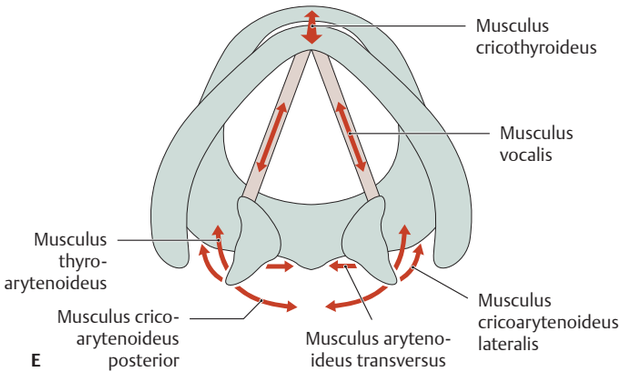


Fig. 13.8 **Musculi laryngis**
A Left lateral oblique view of extrinsic musculi laryngis. **B** Left lateral view of intrinsic musculi laryngis (lamina sinistra cartilaginis thyroideae and epiglottis removed). **C** Posterior view. **D** Left lateral view. **E** Actions (arrows indicate directions of pull).

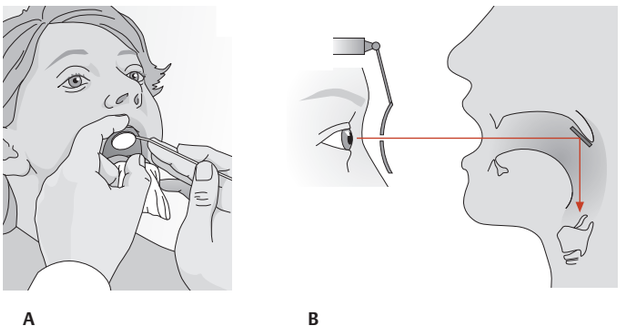
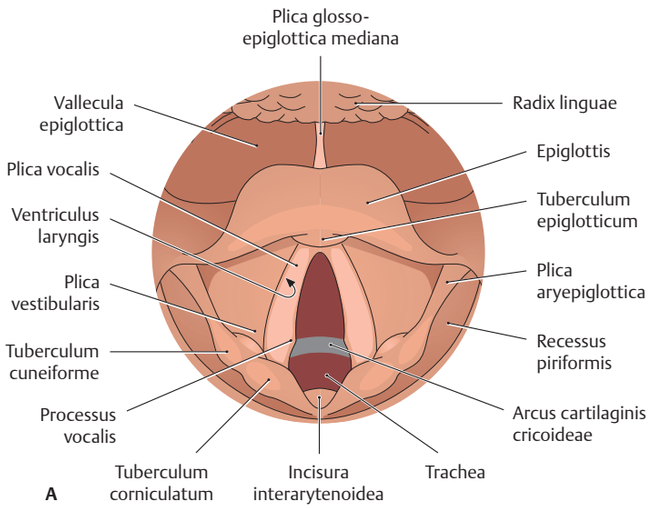


Fig. 13.9 **Indirect laryngoscopy technique**
A Mirror examination of the larynx from the perspective of the examiner. The larynx is not accessible to direct inspection but can be viewed with the aid of a small mirror. The examiner depresses the tongue with one hand while introducing the laryngeal mirror (or endoscope) with the other hand.
A Optical path: The laryngeal mirror is held in front of the uvula, directing light from the examiner's head mirror down toward the larynx. The image seen by the examiner is shown in **Fig. 13.10**.



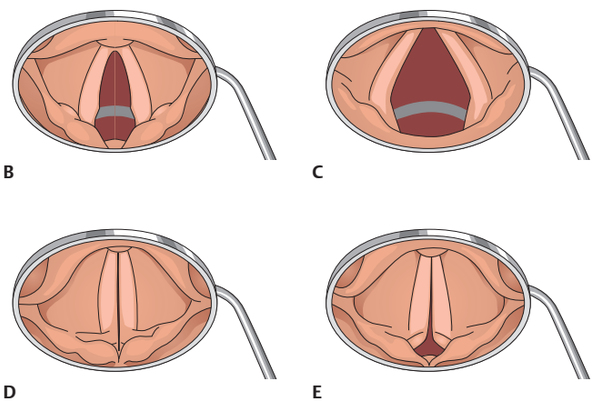
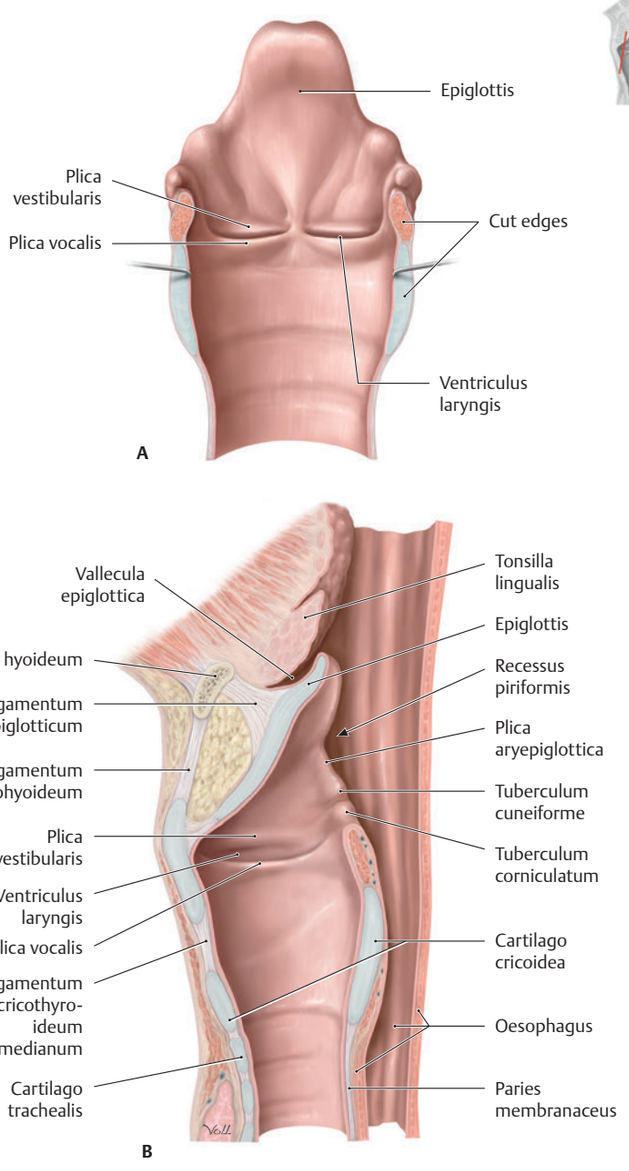


Fig. 13.10 **Indirect laryngoscopy and position of plica vocalis**
A Laryngoscopic mirror image. **B** Normal respiration. **C** Vigorous respiration. **D** Phonation position (plicae vocales completely adducted). **E** Whispered speech (plicae vocales slightly abducted).
Indirect laryngoscopy produces a virtual image of the larynx in which the right plica vocalis appears on the right side of the mirror image and anterior structures (e.g., tongue base, valleculae epiglotticae, and epiglottis) appear at the top of the image. The plicae vocales appear as smooth-edged bands (there are no blood vessels or submucosa below the stratified, nonkeratinized squamous epithelium of the plicae vocales). They are therefore markedly lighter than the highly vascularized surrounding mucosa. The glottis can be evaluated in opened (respiratory) and closed (phonation) position by having the patient alternately inhale and sing "hee." The clinician can then determine pathoanatomical changes (e.g., redness, swelling, and ulceration) and functional changes (e.g., to plica vocalis position).

Larynx: Neurovasculature



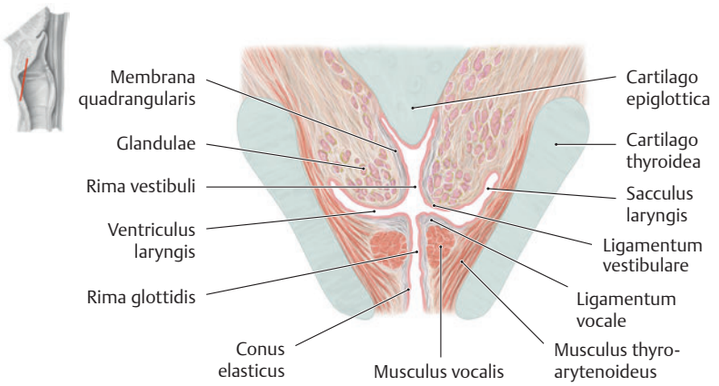


Fig. 13.12 **Plicae vestibulares and vocales**
Coronal histologic section. The plicae vestibulares and vocales are the mucosal coverings of underlying ligaments. The plicae vocales ("vocal cords") contain the ligamentum vocale and musculus vocalis. The fissure between the plicae vocales is the rima glottidis (glottis). The plicae vestibulares ("false vocal cords") are superior to the plicae vocales. They contain the ligamentum vestibulare, the free inferior end of the membrana quadrangularis. The fissure between the plicae vestibulares is the rima vestibuli, which is broader than the rima glottidis. *Note:* The loose connective tissue of the aditus laryngis may become markedly swollen (e. g., insect bite, inflammatory process), obstructing the rima vestibuli. This laryngeal edema (often incorrectly called "glottic edema") presents clinically with dyspnea and poses an asphyxiation risk.

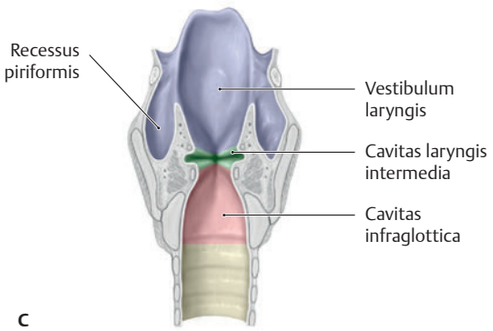
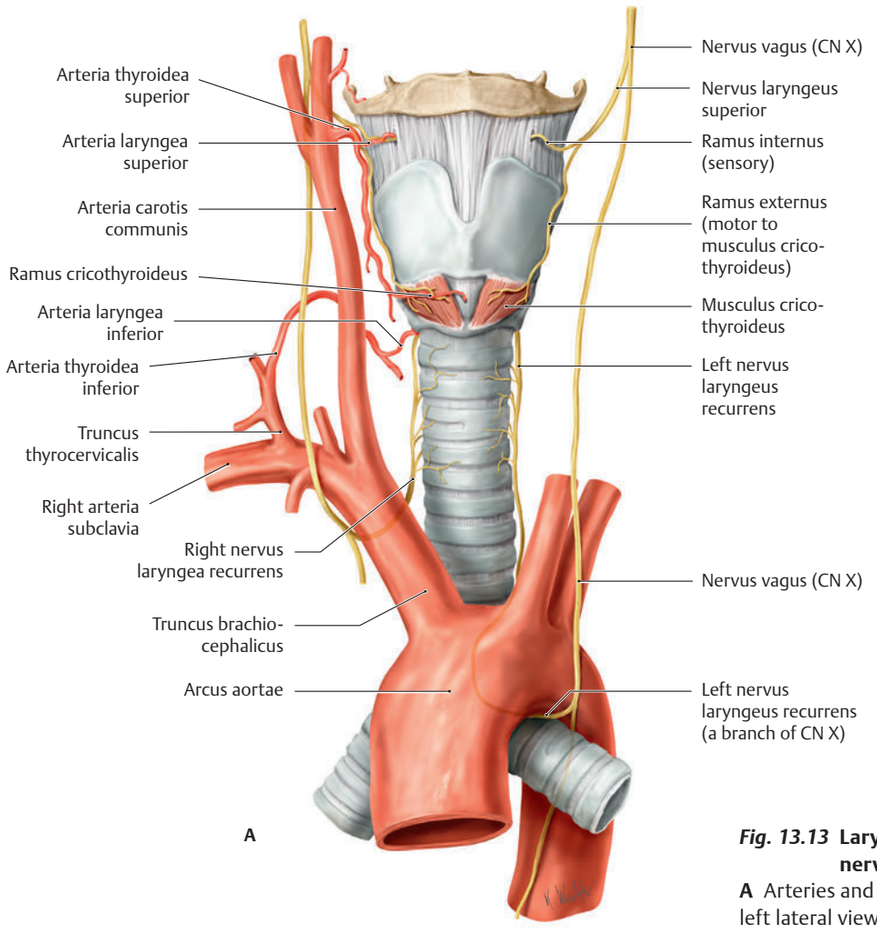


Fig. 13.11 **Laryngeal mucosa**
A Posterior view with pharynx and oesophagus cut along the midline and spread open. **B** Left lateral view of midsagittal section. **C** Posterior view with laryngeal levels.
The larynx lies anterior to the pars laryngea pharyngis. Air enters through the aditus laryngis formed by the epiglottis and plicae aryepiglotticae. Lateral to the plicae aryepiglotticae are pear-shaped mucosal fossae (recessus piriformes), which channel food past the larynx and into the pars laryngea pharyngis and on into the oesophagus. The interior of the larynx is lined with mucous membrane that is loosely applied to its underlying tissue (except at the plicae vocales). The cavitas laryngis can be further subdivided with respect to the plicae vestibulares and vocales (**Table 13.2**).

Table 13.2 **Divisions of the cavitas laryngis**

Laryngeal level	Boundaries
I: Vestibulum laryngis (supraglottic space)	Laryngeal inlet (aditus laryngis) to plicae vestibulares
II: Cavitas laryngis intermedia (transglottic space)	Plicae vestibulares across the ventriculus laryngis (lateral evagination of mucosa) to plicae vocales
III: Cavitas infraglottica (subglottic space)	Plicae vocales to inferior border of cartilago cricoidea



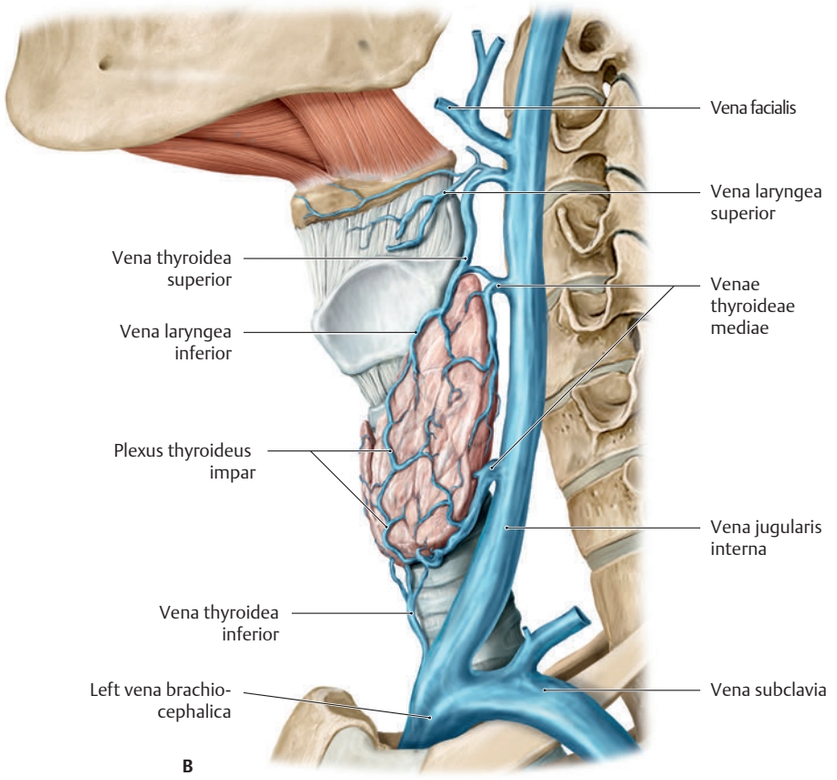


Fig. 13.13 **Laryngeal blood vessels and nerves**

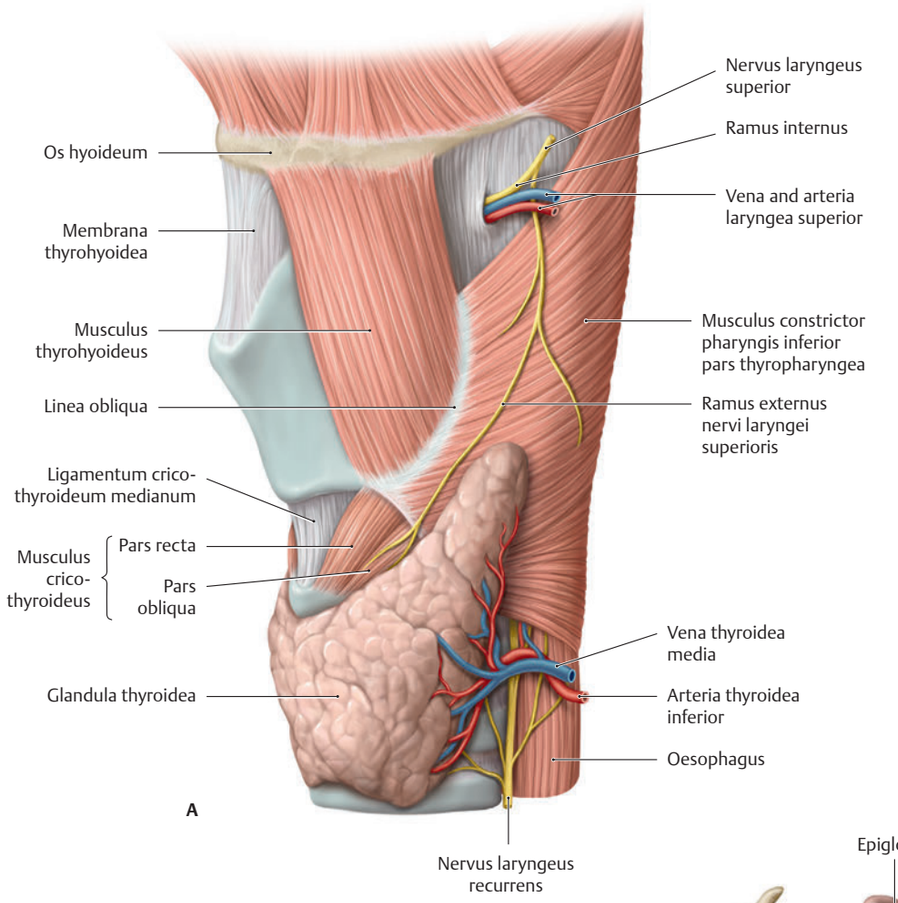
A Arteries and nerves, anterior view. **B** Veins, left lateral view.

Arteries: The larynx derives its blood supply primarily from the arteriae laryngeae superior and inferior. The arteria laryngea superior arises from the arteria thyroidea superior (a branch of the arteria carotis externa). The arteria laryngea inferior arises from the arteria thyroidea inferior (a branch of the truncus thyrocervicalis).

Nerves: The larynx is innervated by the nervus laryngeus superior and the nervus laryngeus recurrens (of the nervus vagus). The nervus laryngeus superior splits into a ramus internus (sensory) and a ramus externus (motor). The ramus externus innervates the musculus cricothyroideus. The remaining intrinsic musculi laryngis receive motor innervation from the nervus laryngeus recurrens, which branches from the nervus vagus below the larynx and ascends. *Note:* The left nervus laryngeus recurrens wraps around the arcus aortae, and the right nervus laryngeus recurrens wraps around the arteria subclavia. A left-sided aortic aneurysm may cause left nervus laryngeus recurrens palsy, resulting in hoarseness (see p. 343).

Veins: The larynx is drained by a vena laryngea superior and a vena laryngea inferior. The vena laryngea superior drains to the vena jugularis interna (via the vena thyroidea superior); the vena laryngea inferior drains to the vena brachiocephalica sinistra (via the plexus thyroideus impar to the vena thyroidea inferior).

Larynx: Topography



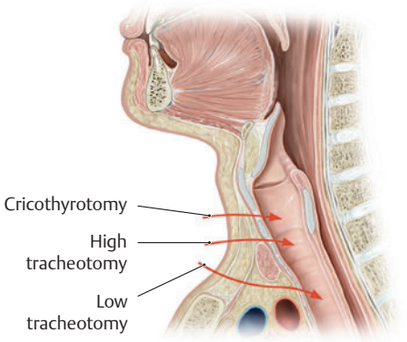


Fig. 13.15 **Approaches to the larynx and trachea**

Midsagittal section, left lateral view. When an acute edematous obstruction of the larynx (e. g., due to an allergic reaction) poses an acute risk of asphyxiation, the following surgical approaches are available for creating an emergency airway:

- Division of the ligamentum cricothyroideum medianum (cricothyrotomy)
- Incision of the trachea (tracheotomy) at a level just below the cartilago cricoidea (high tracheotomy) or just superior to the incisura jugularis sterni (low tracheotomy).

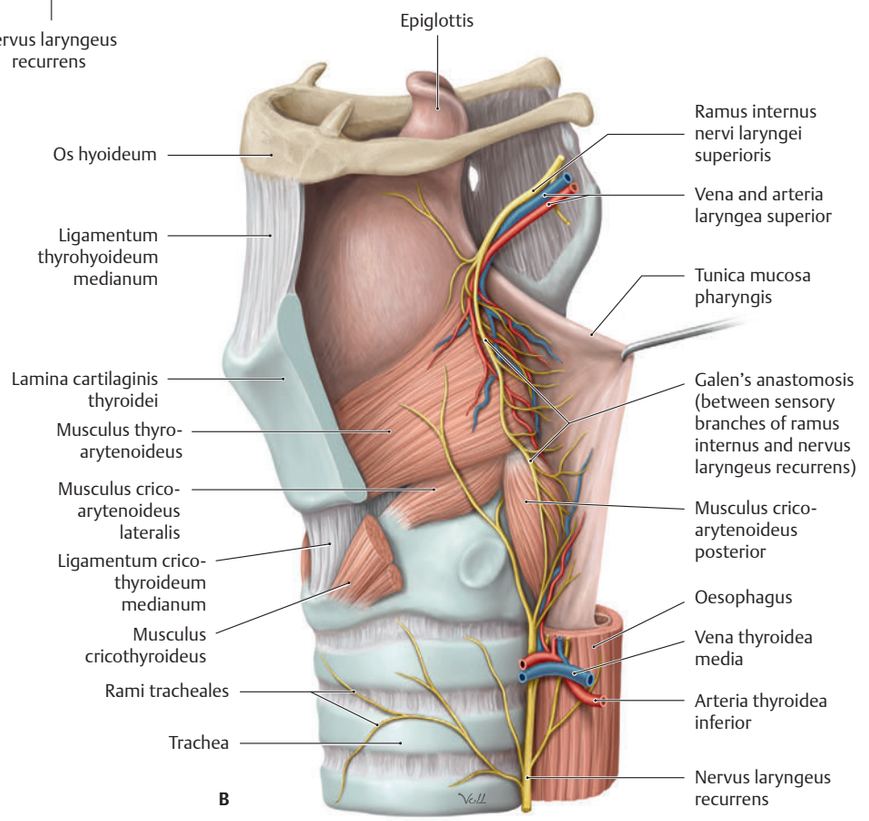


Fig. 13.14 **Topography of the larynx**

Left lateral view. **A** Superficial dissection. **B** Deep dissection (musculus cricothyroideus and lamina sinistra cartilaginis thyroideae removed with tunica mucosa pharyngis retracted).

Neurovascular structures enter the larynx posteriorly. The larynx receives sensory and motor innervation from branches of the nervus vagus (CN X).

Sensory innervation: The upper larynx (above the plicae vocales) receives sensory innervation from the ramus internus nervi laryngei superioris, and the cavitas infraglottica receives sensory innervation from the nervus laryngeus recurrens.

Motor innervation: The musculus cricothyroideus receives motor innervation from the ramus externus nervi laryngei superioris, and the rest of the intrinsic muscles of the larynx receive motor innervation from the nervus laryngeus recurrens.

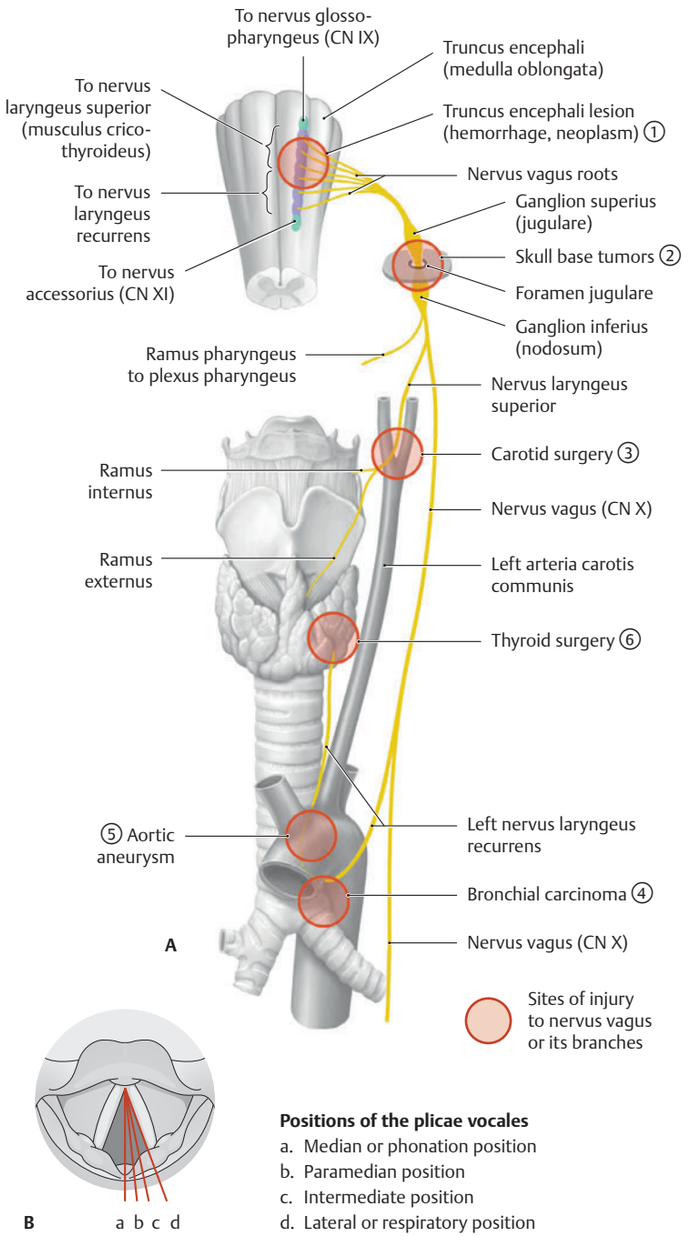


Fig. 13.16 **Nervus vagus lesions**

The nervus vagus (CN X) provides branchiomotor innervation to the pharyngeal and musculi laryngis and somatic sensory innervation to the larynx. *Note:* The nervus vagus also conveys parasympathetic motor fibers and visceral sensory fibers to and from the thoracic and abdominal viscera.

Branchiomotor innervation: The nucleus ambiguus contains the cell bodies of lower motor neurons whose branchiomotor fibers travel in CN IX, X, and XI. The nuclei of the nervus vagus are located in the middle region of the nucleus ambiguus in the truncus encephali (the cranial portions of the nucleus send axons via the nervus glossopharyngeus, and the caudal portions send axons via the nevus accessorius). Fibers emerge from the middle portion of the nucleus ambiguus as roots and combine into CN X, which passes through the foramen jugulare. Branchiomotor fibers are distributed to the plexus pharyngeus via the ramus pharyngeus and the musculus cricothyroideus via the ramus externus (a branch of the nervus laryngeus superior). The remaining branchiomotor fibers leave the nervus vagus as the nervi laryngei recurrentes, which ascend along the trachea to reach the larynx.

Sensory innervation: General somatic sensory fibers travel from the laryngeal mucosa to the spinal nucleus of the nervus trigeminus via the nervus vagus. The cell bodies of these primary sensory neurons are located in the ganglion inferius (nodosum). *Note:* The ganglion superius (jugulare) contains the cell bodies of viscerosensory neurons.

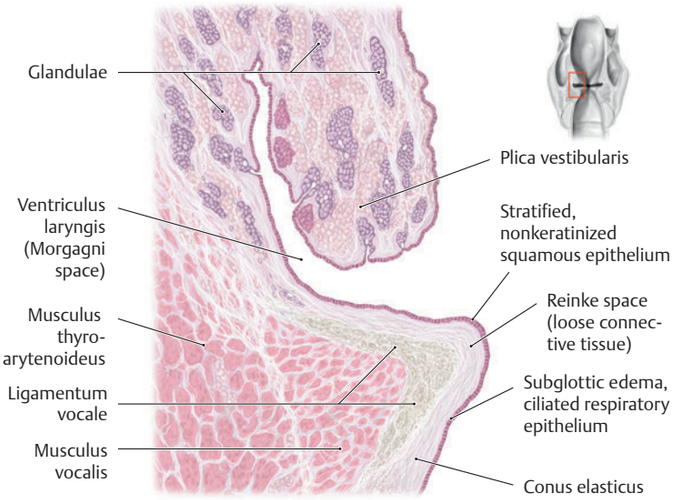


Fig. 13.17 **Plicae vocales**

Schematic coronal histologic section, posterior view. The plica vocalis, which is exposed to severe mechanical stresses, is covered by nonkeratinized squamous epithelium, unlike the adjacent subglottic space, which is covered by ciliated respiratory epithelium. The mucosa of the plicae vocales and subglottic space overlies loose connective tissue. Chronic irritation of the subglottic mucosa (e.g., from cigarette smoke) may cause chronic edema in the subglottic space, resulting in a harsh voice. Degenerative changes in the plica vocalis mucosa may lead to thickening, loss of elasticity, and squamous cell carcinoma.

Table 13.3 **Nervus vagus lesions**

Lesions of the laryngeal nerves (**Fig. 13.16A**) may cause sensory loss or motor paralysis, which disrupts the position of the plicae vocales (**Fig. 13.16B**).

Level of nerve lesion and effects on position of plica vocalis		Sensory loss
① Central lesion (truncus encephali or higher)		
E.g., due to tumor or hemorrhage. Spastic paralysis (if nucleus ambiguus is disrupted), flaccid paralysis, and muscle atrophy (if motor neurons or axons are destroyed).	b,c	None
② Skull base lesion*		
E.g., due to nasopharyngeal tumors. Flaccid paralysis of all intrinsic and extrinsic musculi laryngis on affected side. Glottis cannot be closed, causing severe hoarseness.	b,c	Entire affected (ipsilateral) side
③ Nervus laryngeus superior lesions*		
E.g., due to carotid surgery. Hypotonicity of the musculus cricothyroideus, resulting in mild hoarseness with a weak voice, especially at high frequencies.	d	Above plica vocalis
④, ⑤, ⑥ Nervus laryngeus recurrens lesions**		
E.g., due to bronchial carcinoma ④, aortic aneurysm ⑤, or thyroid surgery ⑥. Paralysis of all intrinsic musculi laryngis on affected side. This results in mild hoarseness, poor tonal control, rapid voice fatigue, but not dyspnea.	a,b	Below plica vocalis

*Other motor deficits include drooping of the palatum molle and deviation of the uvula toward the affected side, diminished gag and cough reflexes, difficulty swallowing (dysphagia), and hypernasal speech due to deficient closure of the pharyngeal isthmus. Sensory defects include the sensation of a foreign body in the throat.

**Transection of both nervi laryngei recurrentes can cause significant dyspnea and inspiratory stridor (high-pitched noise indicating obstruction), necessitating tracheotomy in acute cases.

Endotracheal Intubation

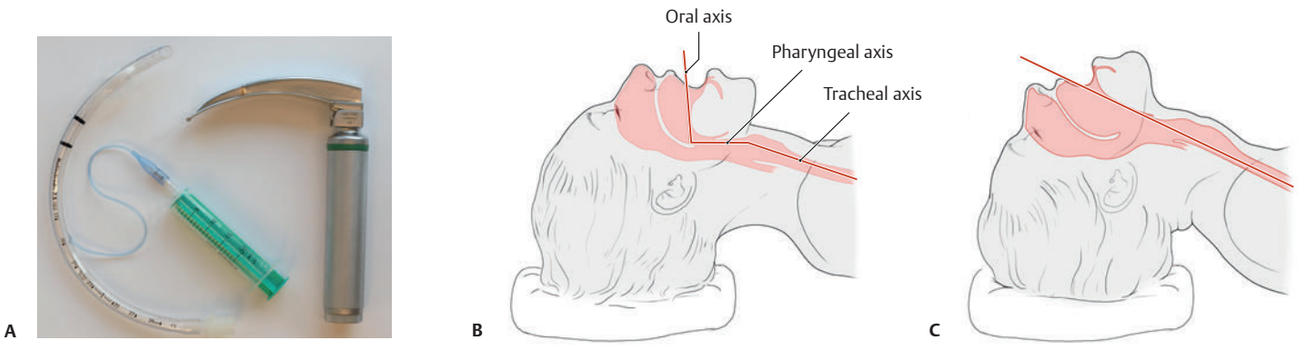


Fig. 13.18 **Equipment and positioning of the head for endotracheal intubation**

A Endotracheal (ET) tube with an inflatable cuff (left) and laryngoscope with handle and curved spatula (right).

B, C Unfavorable and optimal positioning of the head for endotracheal intubation.

Endotracheal intubation, inserting a tube into the trachea of a patient, is the safest way to keep the airways clear to allow for effective ventilation. Depending on access there are four ways to achieve endotracheal intubation:

- orotracheal = via the mouth (gold standard),
- nasotracheal = via the nose (performed if orotracheal intubation is not possible), and
- pertracheal = intubation through tracheostomy (used for longterm ventilation), and
- cricothyrotomy (used only in an emergencies when there is the threat of impending suffocation).

Endotracheal intubation requires the use of a laryngoscope and an ET tube **(A)**. The tubes are available in different sizes (10–22 cm) and diameters (2.5–8 mm). They have a circular cross piece that has a proximal connector for a ventilation hose and a beveled distal end. An inflatable cuff on the ET ensures that the trachea is hermetically sealed (see **Fig. 13.20**). With orotracheal intubation, the oral, pharyngeal, and tracheal axes should lie on a straight line (the so-called "sniffing position", see **C**).This facilitates direct visualization of the laryngeal inlet (see **Fig. 13.19**) and shortens the distance between the teeth and glottis in young adults (13–16 cm).

Note: In patients with suspected cervical spine injury, manipulation of the head position without maintaining the stability of the cervical spine is contraindicated.

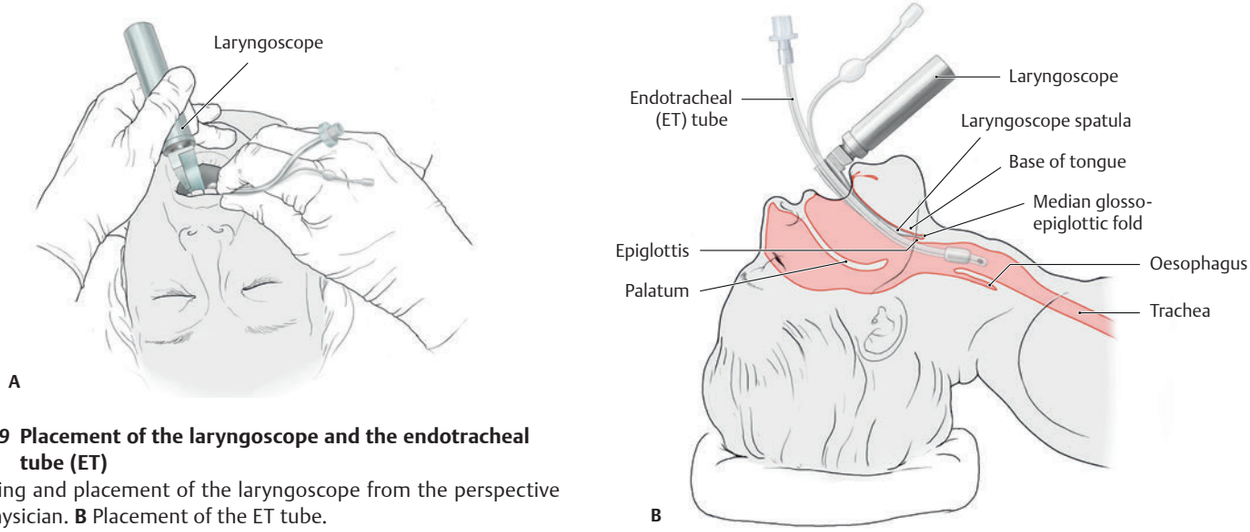


Fig. 13.19 **Placement of the laryngoscope and the endotracheal tube (ET)**

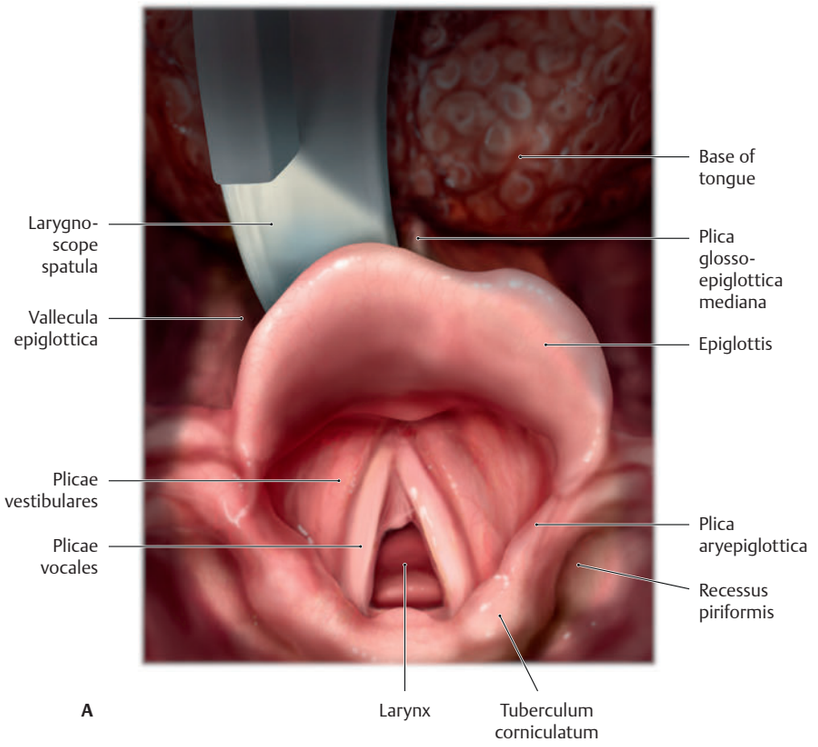
A Handling and placement of the laryngoscope from the perspective of the physician. **B** Placement of the ET tube.

To place the ET tube, the physician stands at the head of the patient and introduces the spatula of the laryngoscope into the patient's mouth. The spatula is then used to push the patient's tongue to the left to get a clear view of the larynx.

Under direct visualization, the spatula tip is then advanced until it lies in the vallecula epiglottica. Note: If the spatula is introduced too deep, its tip reaches behind the epiglottis, and orientation is difficult.

The physician then pulls the spatula in the direction of floor of mouth without using the upper teeth as a fulcrum. This elevates the epiglottis and the base of the tongue such that the physician now has an unobstructed view of the aditus laryngis (see **Fig. 13.20A**). The physician then pushes the ET tube through the rima glottis into the trachea (see **Fig. 13.20B**). Placement under laryngoscopic control ensures that the ET tube is placed in the trachea and does not accidentally enter the esophagus.

Note: The ET tube has markings in centimeter increments that serve as an orientation aid to the physician. The distance from the upper teeth to the center of the trachea in the adult is about 22 cm and in newborns is about 11 cm. Distances greater than these might indicate that the tube is inserted too deeply and is in the bronchus principalis dexter.



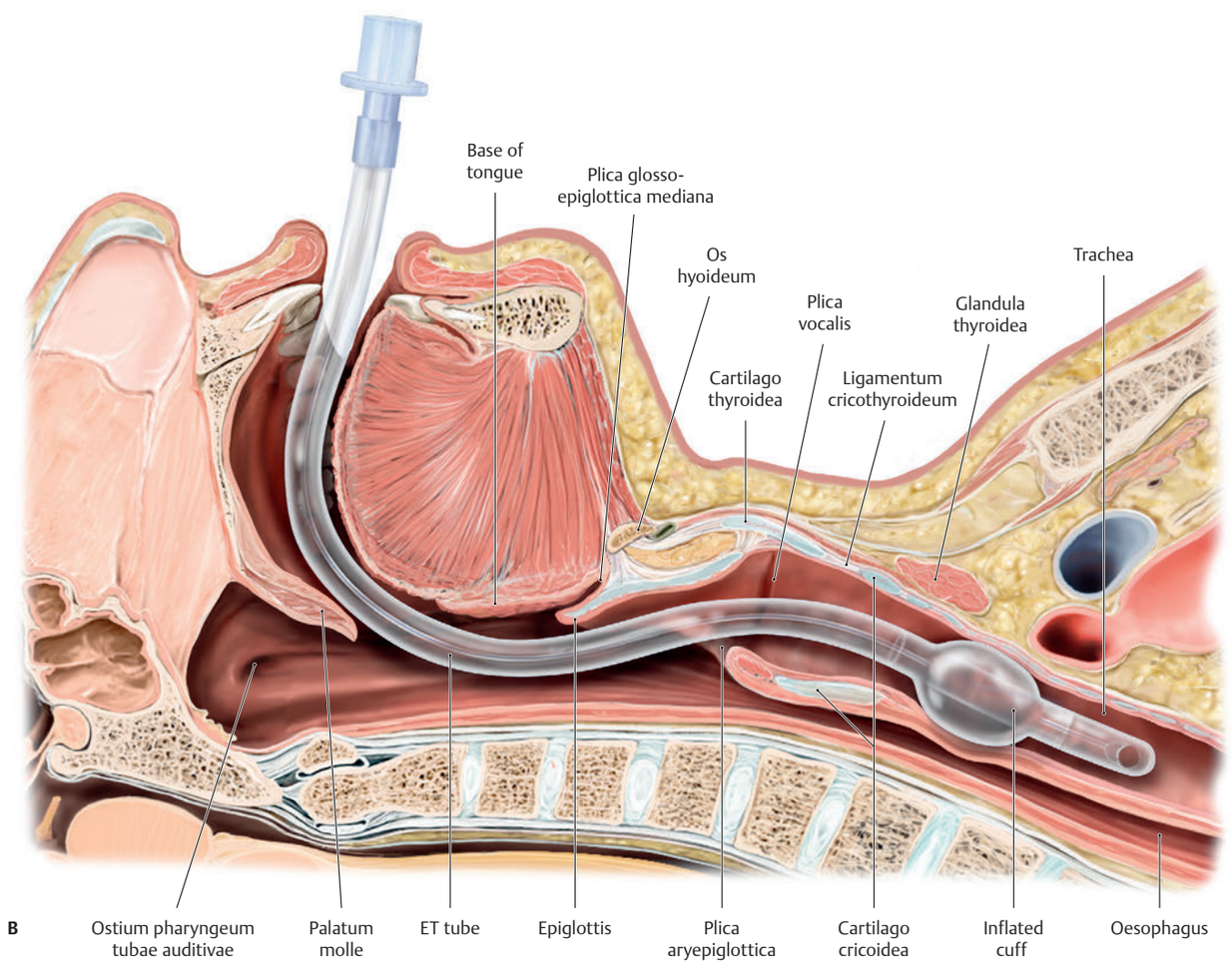


Fig. 13.20 **View of the aditus laryngis and location of the endotracheal tube after intubation**

A Laryngoscopic view of larynx, epiglottis, and plica glossoepiglottica mediana. **B** Median sagittal section viewed from the right of an ET tube in situ with its cuff inflated.

The inflatable cuff seals the trachea in all directions and eliminates leakage during ventilation and prevents aspiration of foreign bodies, mucus, or gastric juice.

To check if the ET tube has been placed correctly, the physician looks at the patient's chest to evaluate whether chest movement is symmetrical and auscultates for equal breath sounds over both lung fields and the ab-sence of breath sounds over the stomach. Further indicators that the ET tube is placed correctly include vapor condensation on the inside of the ET tube with exhalation and measurement of endtidal carbon dioxide. If there is any doubt as to the positioning of the tube, it should be removed.

Glandulae Thyroidea & Parathyroideae

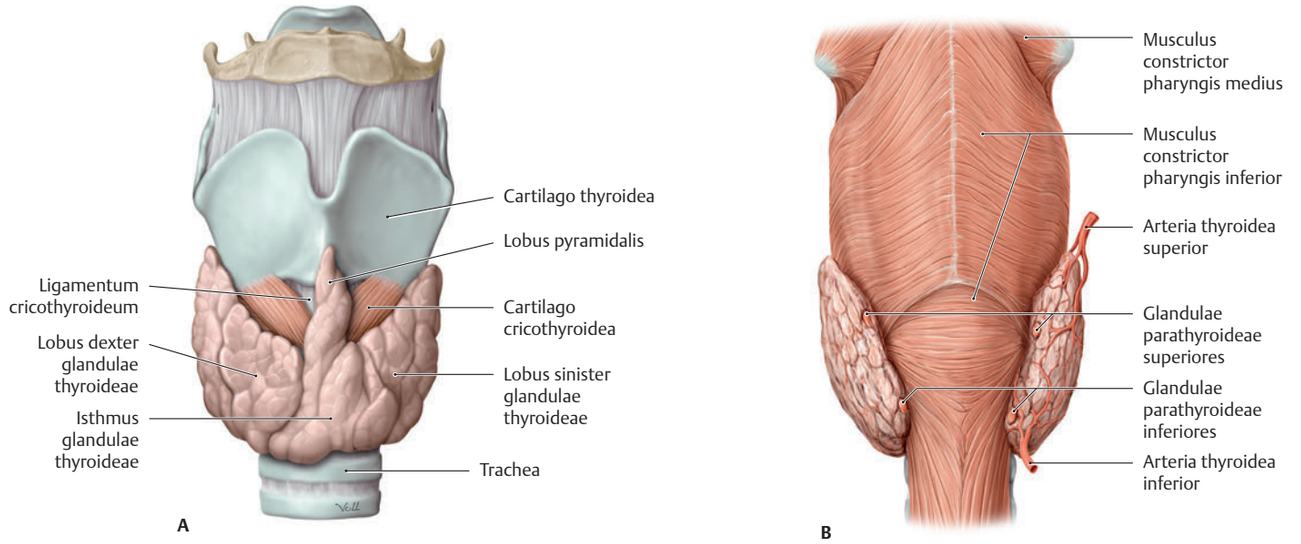


Fig. 13.21 **Glandulae thyroidea and parathyroideae**
A Anterior view. **B** Posterior view.
The glandula thyroidea consists of two laterally situated lobes and a central narrowing (isthmus). A lubus pyramidalis may be found in place of the isthmus; the apex points to the embryonic origin of the glandula thyroidea at the base of the tongue (on occasion, a persistent ductus thyroglossus may be present, connecting the lobus pyramidalis with the foramen caecum of the tongue). The glandulae parathyroideae (generally four in number) show considerable variation in number and location. *Note:* Because the glandulae parathyroideae are usually contained within the capsula fibrosa, there is considerable risk of inadvertently removing them during thyroid surgery. This causes decreased plasma calcium (Ca^{2+}) levels, resulting in tetany (muscle twitching and cramps). Tetany involving the laryngeal and respiratory muscles may cause dyspnea (shortness of breath), which could be fatal if untreated.

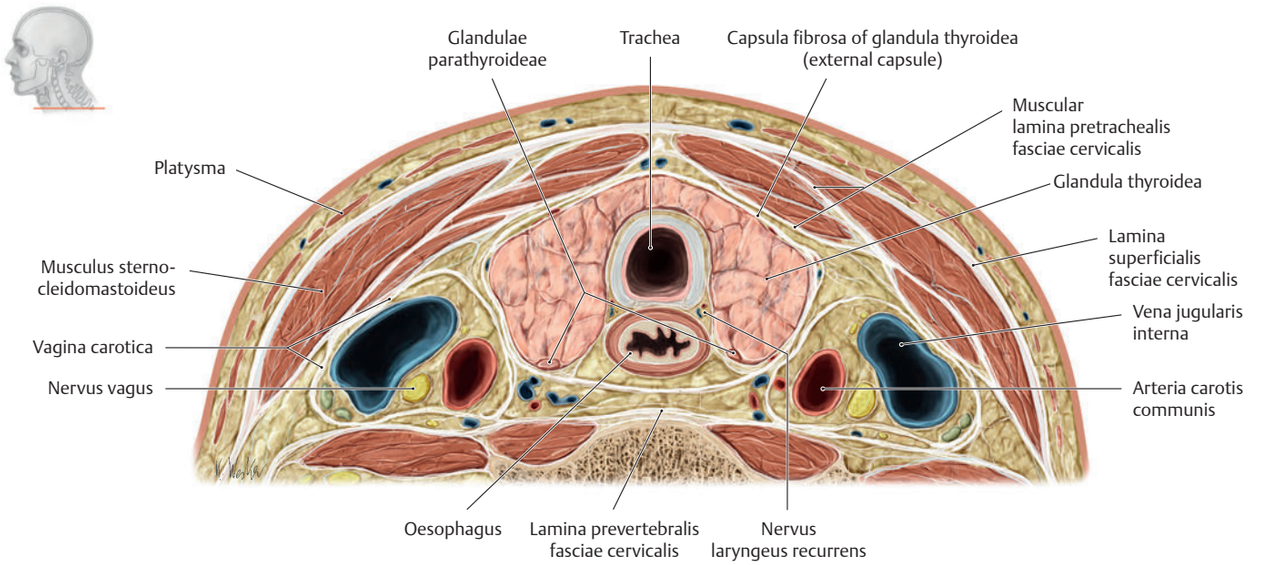


Fig. 13.22 **Topography of the glandula thyoridea**
Transverse section through the neck at the T1 level, superior view. The glandula thyroidea partially surrounds the trachea and is bordered postero-laterally by the vagina carotica. When the glandula thyroidea is pathologically enlarged (e. g., due to iodine-deficiency goiter), it may gradually compress and narrow the tracheal lumen, causing respiratory distress. The glandula thyroidea is surrounded by a capsula fibrosa composed of an internal and external layer. The delicate internal layer (*internal capsule*, not shown here) directly invests the glandula thyroidea and is fused with its glandular parenchyma. Vascularized fibrous slips extend from the internal capsule into the substance of the gland, subdividing it into lobuli. The internal capsule is covered by the tough *external capsule*, which is part of the lamina pretrachealis of the fascia cervicalis. This capsule invests the glandula thyroidea and glandulae parathyroideae and is also called the "surgical capsule" because it must be opened to gain surgical access to the glandula thyoridea. Between the external and internal capsules is a potential space that is traversed by vascular branches and is occupied by the glandulae parathyroideae.

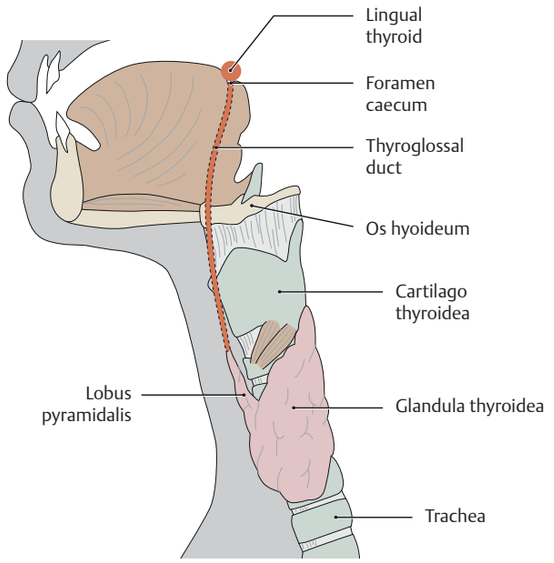


Fig. 13.23 **Ectopic glandula thyoridea**
Left lateral view. Ectopic thyroid is a rare condition in which the entire glandula thyroidea or thyroid tissues are found outside their normal position in the neck inferolateral to the cartilago thyroidea. Dentists may encounter this as a firm midline mass on the dorsal tongue, just posterior to the foramen caecum (the embryonic origin on the glandula thyoridea). This mass may appear as light pink to bright red, and may be regular or irregular. This is known as a lingual thyroid and represents approximately 90% of ectopic thyroid cases. Symptoms of lingual thyroid may include cough, pain, dysphagia (difficulty swallowing), dysphonia (difficulty speaking), and dyspnea (shortness of breath). Treatment involves administration of thyroxine to suppress thyroid stimulating hormone (TSH) production and therefore reduce the size of the mass. Surgical excision may be necessary if symptoms are severe, especially if they threaten the airway.

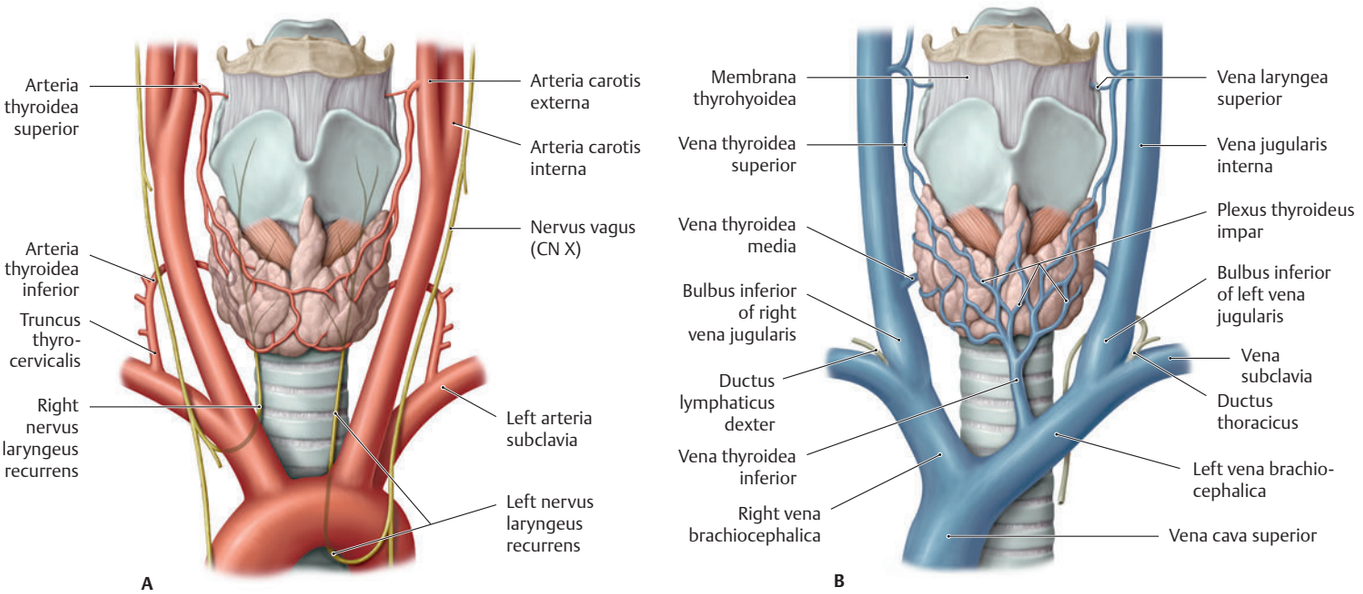
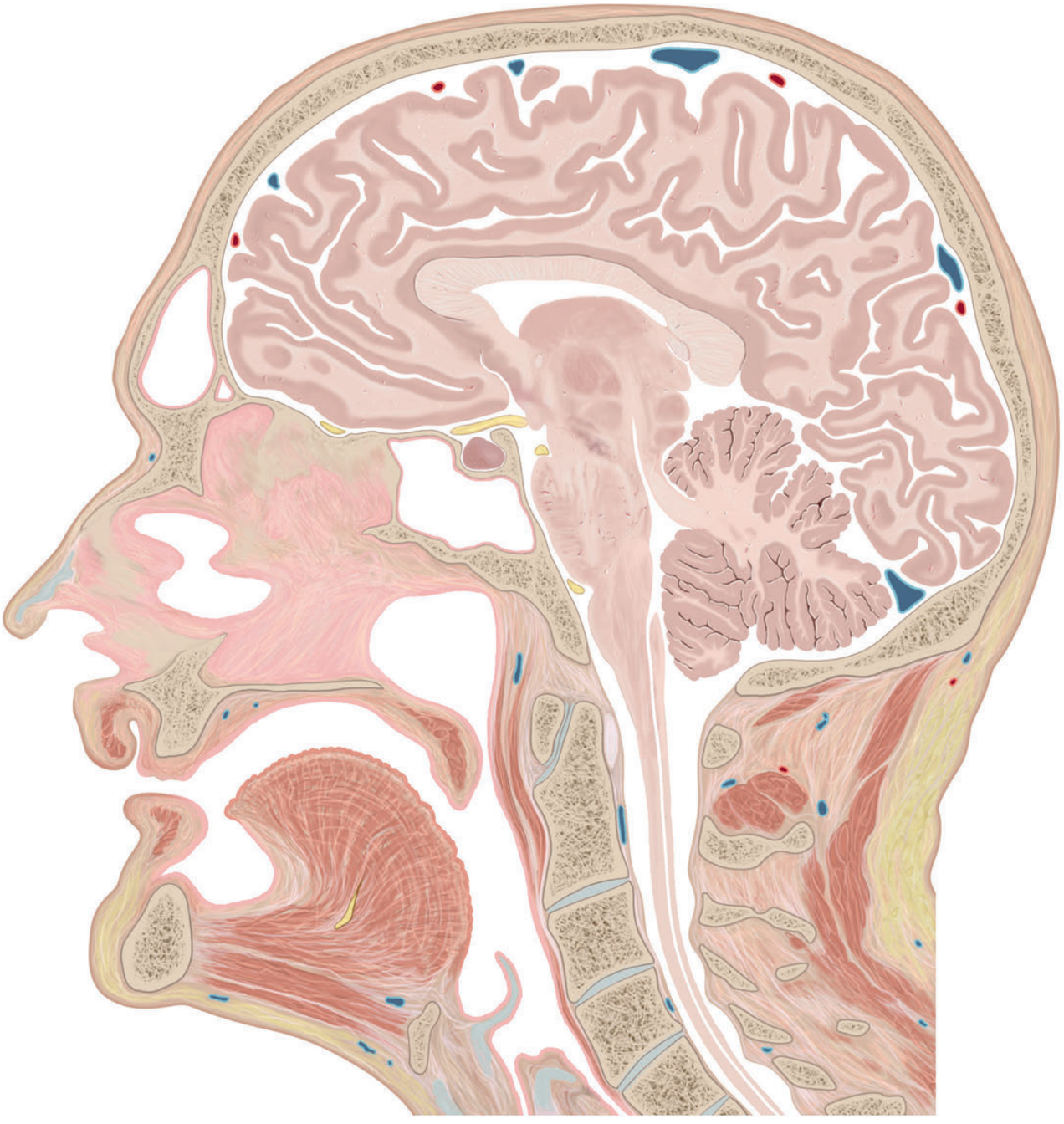


Fig. 13.24 **Blood supply and innervation of the glandula thyroidea**
Anterior view.

A **Arterial supply:** The glandula thyroidea derives most of its arterial blood supply from the arteriae thyroideae superior and inferior. The arteria thyroidea superior, a branch of the arteria carotis externa, runs forward and downward to supply the gland. It is supplied from below by the arteria thyroidea inferior, which branches from the truncus thyrocervicalis. All of these arteries, which course on the right and left sides of the organ, must be ligated during surgical removal of the glandula thyoridea. In addition, a rare branch, the arteria thyroidea ima, may arise from the truncus brachiocephalicus or right arteria carotis communis to supply the gland from below. It is a potential source of bleeding when performing midline procedures on the neck, for example, a tracheostomy.

Note: Operations on the glandula thyroidea carry a risk of injury to the nervus laryngeus recurrens, which is closely related to the posterior surface of the gland. Because it supplies important laryngeal muscles, unilateral injury to the nerve will cause postoperative hoarseness; bilateral injury may additionally result in dyspnea (difficulty in breathing). Prior to thyroid surgery, therefore, an otolaryngologist should confirm the integrity of the nerve supply to the laryngeal muscles and exclude any preexisting nerve lesion.

B **Venous drainage:** The glandula thyroidea is drained anteroinferiorly by a well-developed *plexus thyroideus impar*, which usually drains through the vena thyroidea inferior to the left vena brachiocephalica. Blood from the glandula thyroidea also drains to the vena jugularis interna via the venae thyroideae superior and mediae.



Sectional Anatomy

14 Sectional Anatomy of the Head & Neck

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Coronal Sections of the Head (I): Anterior

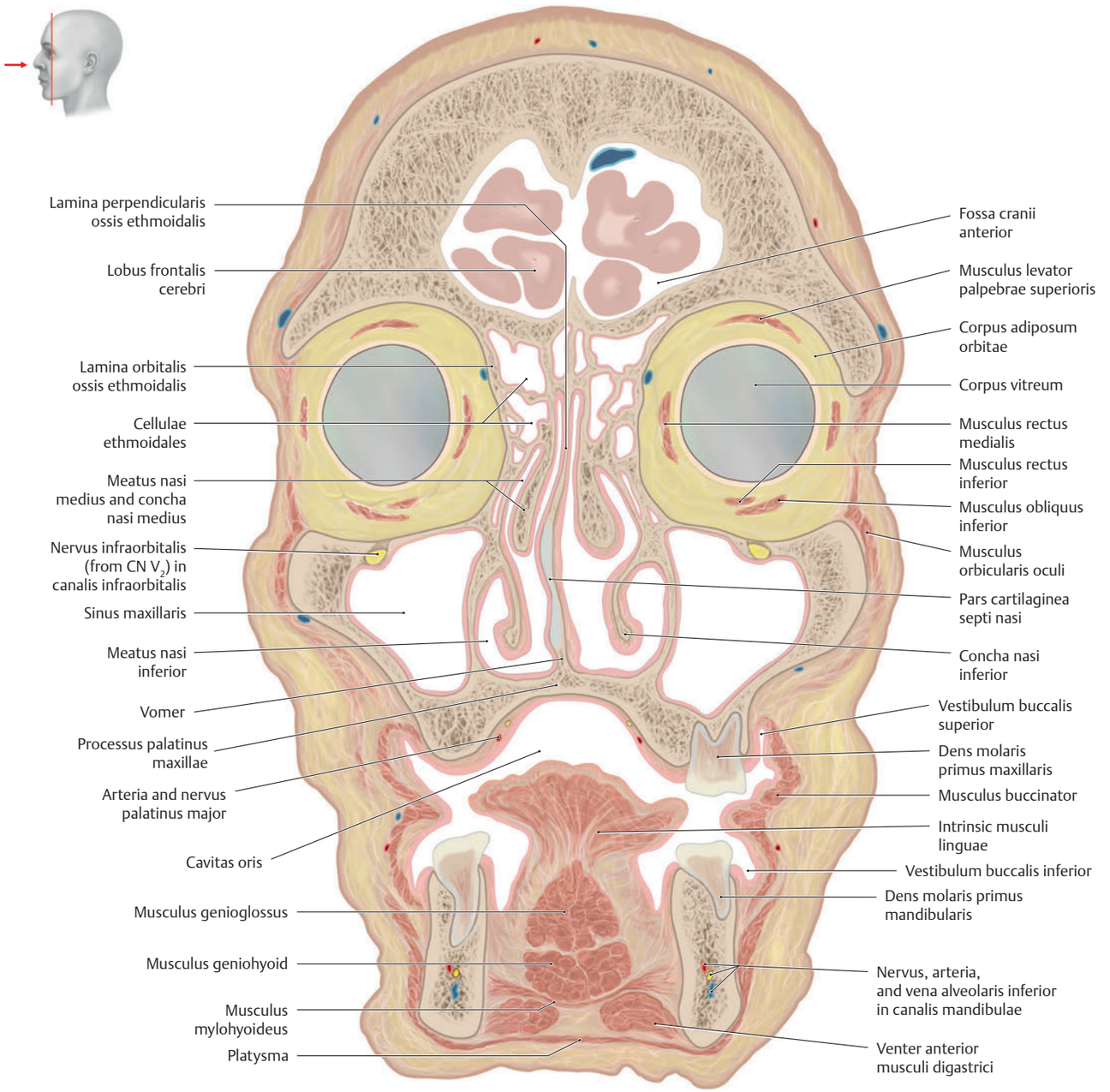


Fig. 14.1 **Coronal section through the anterior orbital margin**
Anterior view. This section of the skull can be roughly subdivided into four regions: the cavitas oris, the cavitas nasi and sinus paranasales, the orbita, and the fossa cranii anterior. Inspecting the region in and around the **cavitas oris**, we observe the muscles of the oral floor, the apex linguae, the neurovascular structures in the canalis mandibulae, and the dens molaris primus. The palatum durum separates the cavitas oris from the **cavitas nasi**, which is divided into left and right halves by the septum nasi. The conchae nasi inferior and media can be identified along with the laterally situated sinus maxillaris. Notice in **Fig 14.2** and **14.3**, as the coronal sections progress backward through the eye, the concha nasi media no longer is associated with the cellulae ethmoidales but instead with the sinus maxillaris. The structure bulging down into the roof of the sinus is the canalis infraorbitalis, which transmits the nervus infraorbitalis (branch of the nervus maxillaris division of the nervus trigeminus, CN V_2). The plane of section is so far anterior that it does not cut the lateral bony walls of the **orbitae** because of the lateral curvature of the skull. The section passes through the transparent corpus vitreum and three of the six extraocular muscles, which can be identified in the corpus adiposum orbitae. Two additional muscles can be seen in the next deeper plane of section (**Fig. 14.2**). The space between the two orbits is occupied by the cellulae ethmoidales. *Note:* The bony lamina orbitalis is very thin (lamina papyracea) and may be penetrated by infection, trauma, and neoplasms.
In the **fossa cranii anterior**, the section passes through both lobi frontales of the brain in the most anterior portions of the cerebral substantia grisea. Very little substantia alba is visible at this level.

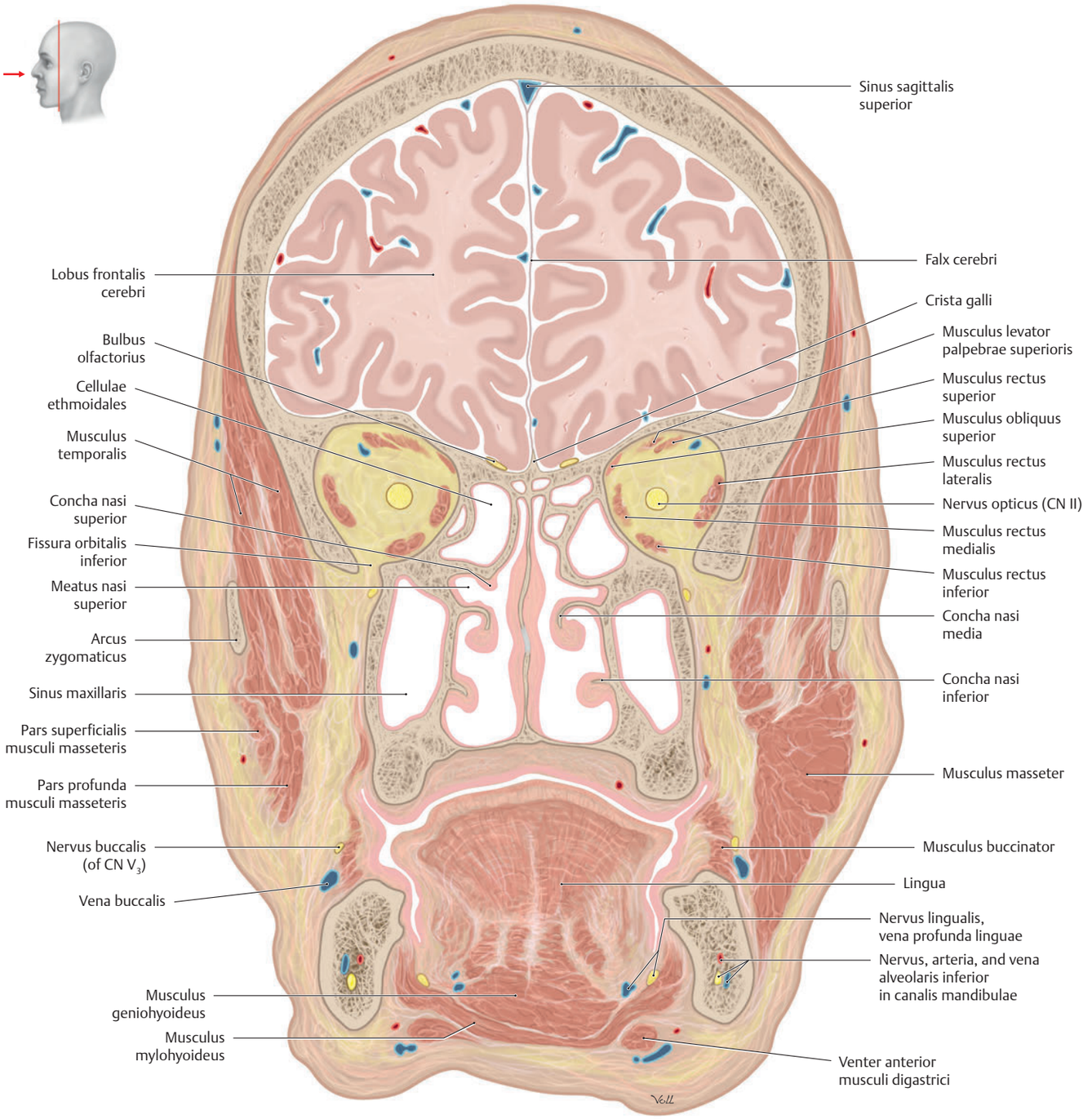


Fig. 14.2 **Coronal section through the retrobulbar space**
Anterior view. Here, the tongue is cut at a more posterior level than in **Fig. 14.1** and therefore appears broader. In addition to the oral floor muscles, we see the musculi masticatorii on the sides of the skull. In the orbital region we can identify the retrobulbar space with its fatty tissue, the extraocular muscles, and the nervus opticus. The orbita communicates laterally with the fossa infratemporalis through the fissura orbitalis inferior. This section cuts through both bulbi olfactorii in the fossa cranii anterior, and the sinus sagittalis superior can be recognized in the midline.

Coronal Sections of the Head (II): Posterior

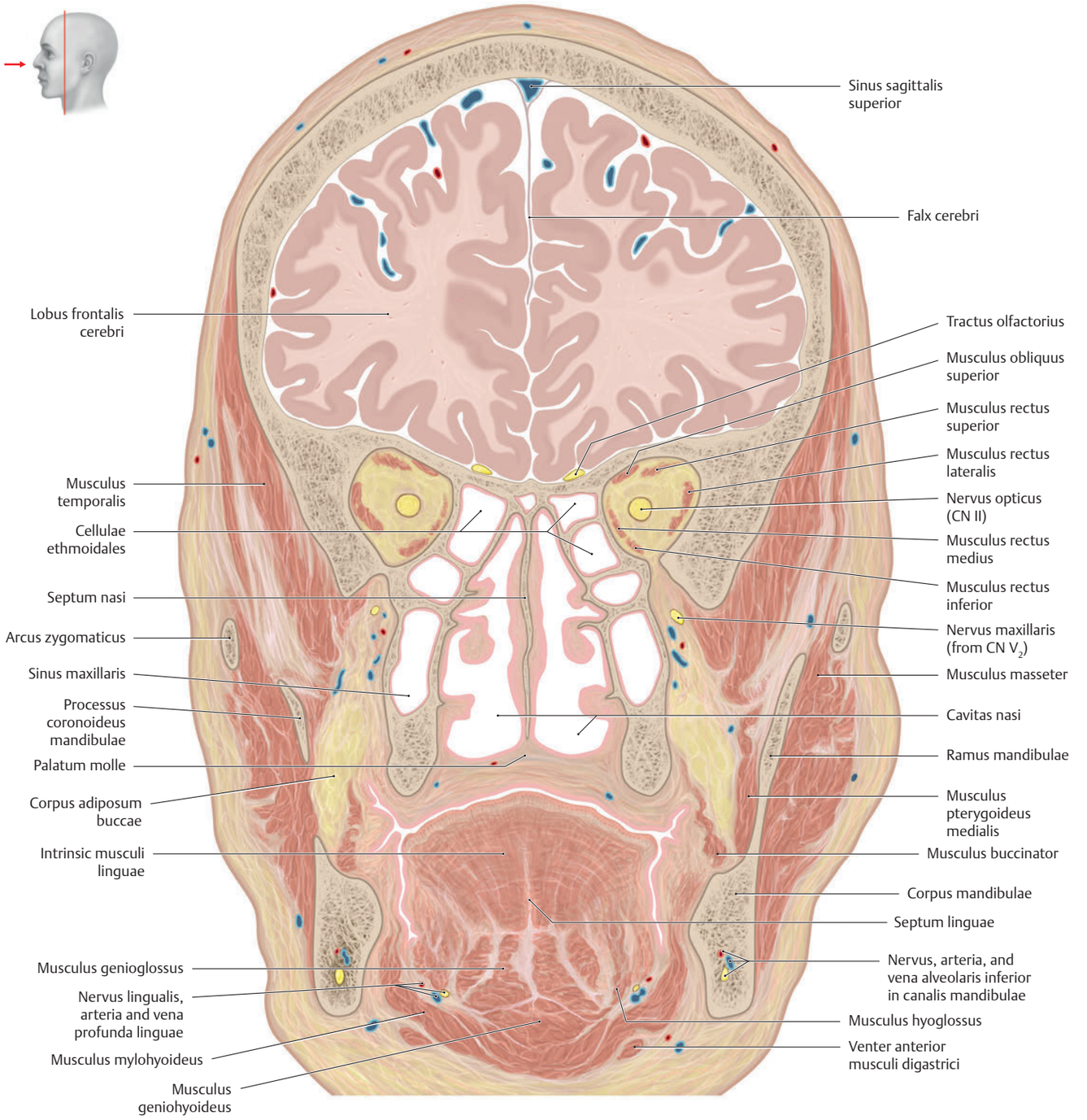


Fig. 14.3 **Coronal section through the orbital apex**
Anterior view. The palatum molle replaces the palatum durum in this plane of section, and the septum nasi becomes osseous at this level. The corpus adiposum buccae is also visible in this plane. The corpus adiposum buccae is reduced in wasting diseases; this is why the cheeks are sunken in patients with end-stage cancer. This coronal section is slightly angled, producing an apparent discontinuity in the ramus mandibulae on the left side of the figure (compare with the continuous ramus on the right side).

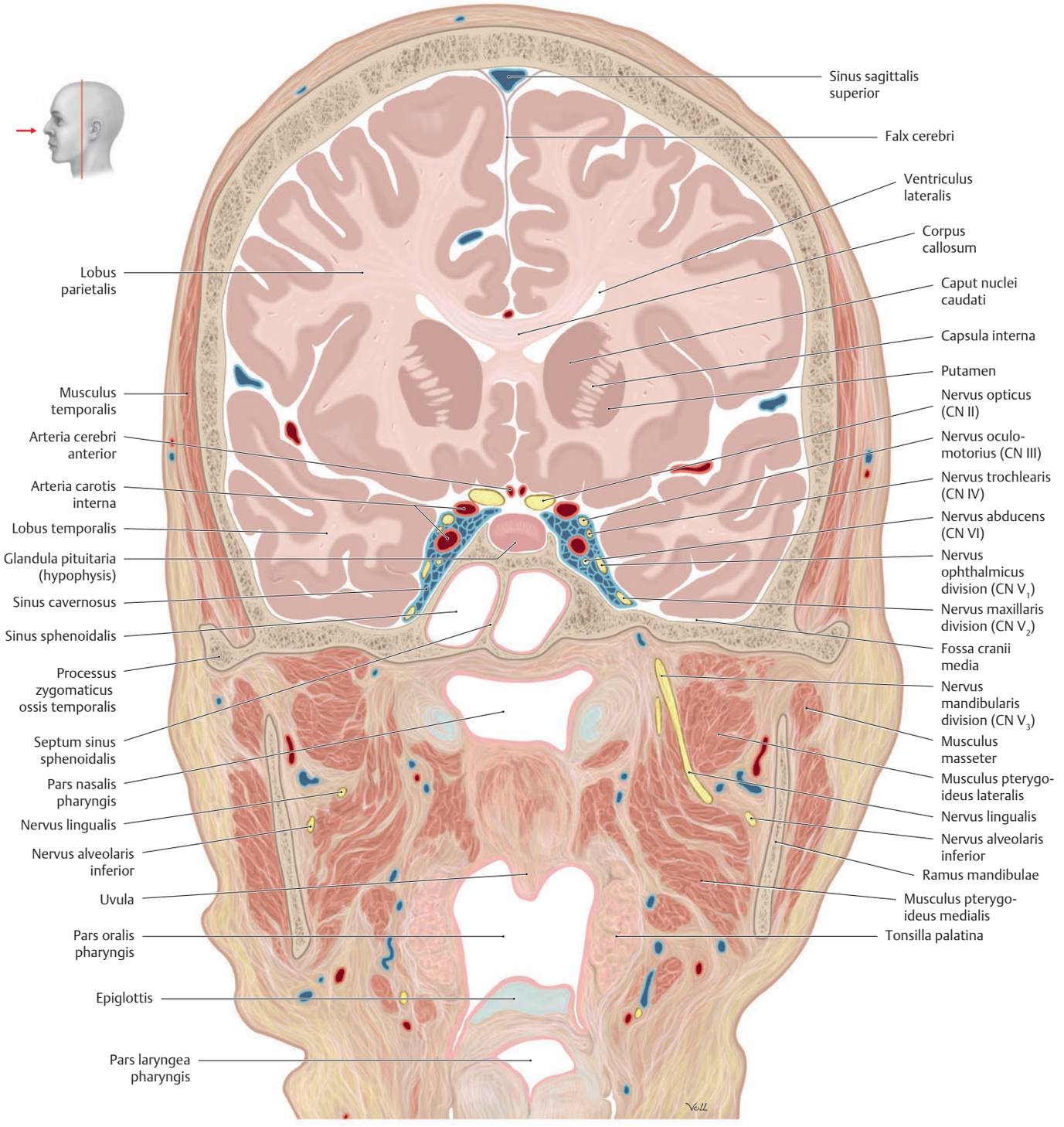


Fig. 14.4 **Coronal section through the hypophysis**
Anterior view. The pars nasalis pharyngis, pars oralis pharyngis, and pars laryngea pharyngis can now be identified. This section cuts the epiglottis, below which is the supraglottic space. The plane cuts the ramus mandibulae on both sides, and a relatively long segment of the nervus mandibularis division of the nervus trigeminus (CN V_3) can be identified on the left side. Above the roof of the sinus sphenoidales is the glandula pituitaria (hypophysis), which lies in the fossa hypophysialis. In the cavitas cranii, the plane of section passes through the fossa cranii media. Due to the presence of the siphon caroticum (a 180-degree bend in the pars cavernosa of the arteria carotis interna), the section cuts the arteria carotis internay twice on each side. Nervi craniales can be seen passing through the sinus cavernosus on their way from the fossa cranii media to the orbita. The sinus sagittalis superior appears in cross-section at the attachment of the falx cerebri. At the level of the cerebrum, the plane of section passes through the lobi parietalis and temporalis.

Coronal MRIs of the Head

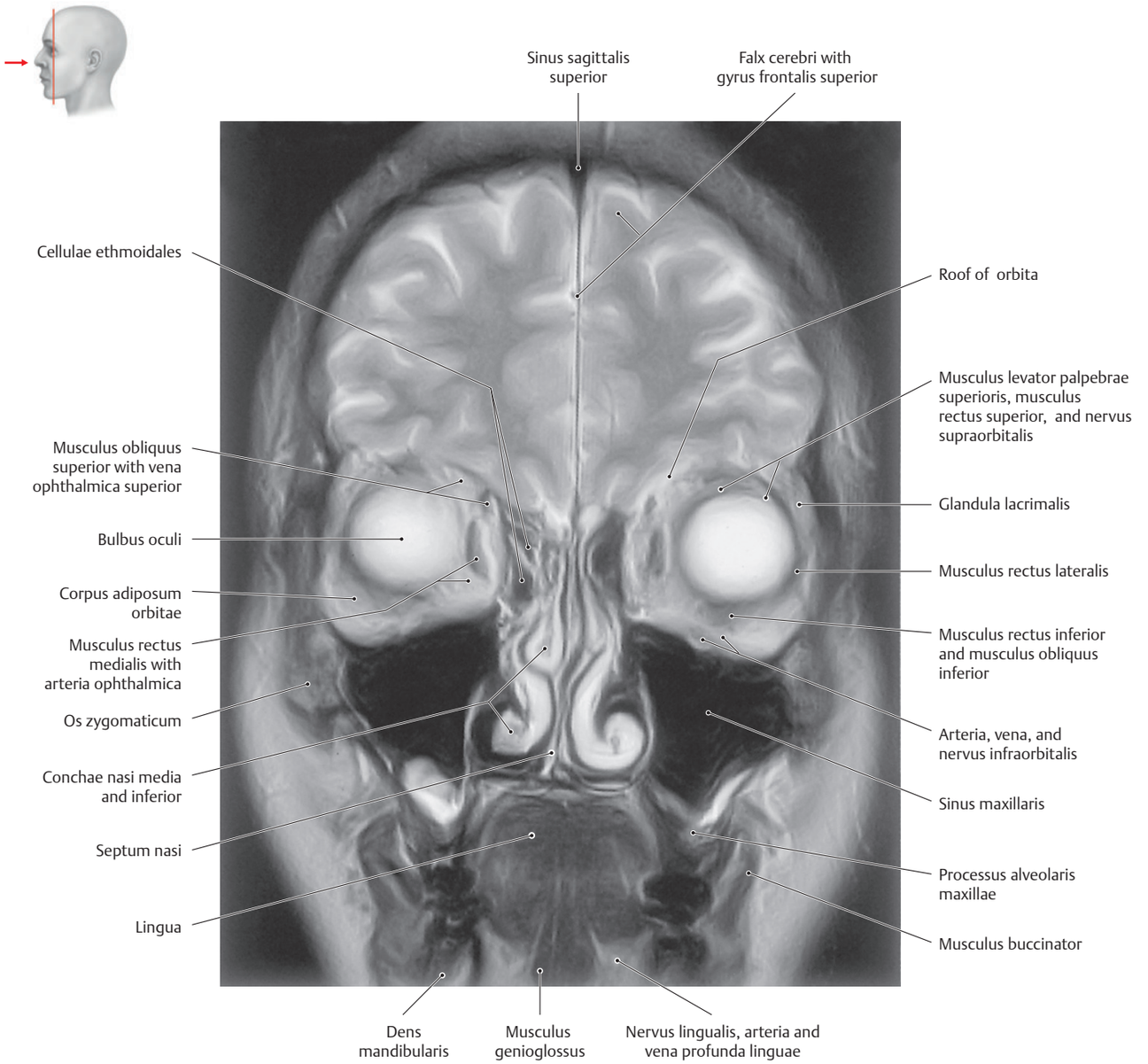


Fig. 14.5 **Coronal MRI through the bulbus oculi**
Anterior view. In this plane of section, the falx cerebri completely divides the hemispheria cerebri. The extraocular muscles can be used to find the orbital neurovasculature: the nervus supraorbitalis runs superior to the musculus levator palpebrae superioris and musculus rectus superior, the vena ophthalmica superior runs medial and superior to the musculus obliquus superior, and the arteria ophthalmica runs inferior to the musculus rectus medialis. The canalis infraorbitalis (containing the arteria, vena, and nervus infraorbitalis) runs inferior to the musculi rectus and obliquus inferiores. The region medial to the dens mandibularis and lateral to the musculus genioglossus contains the glandula sublingualis as well as the nervus lingualis, arteria and vena profunda linguae, nervus hypoglossus (CN XII), and ductus submandibularis.

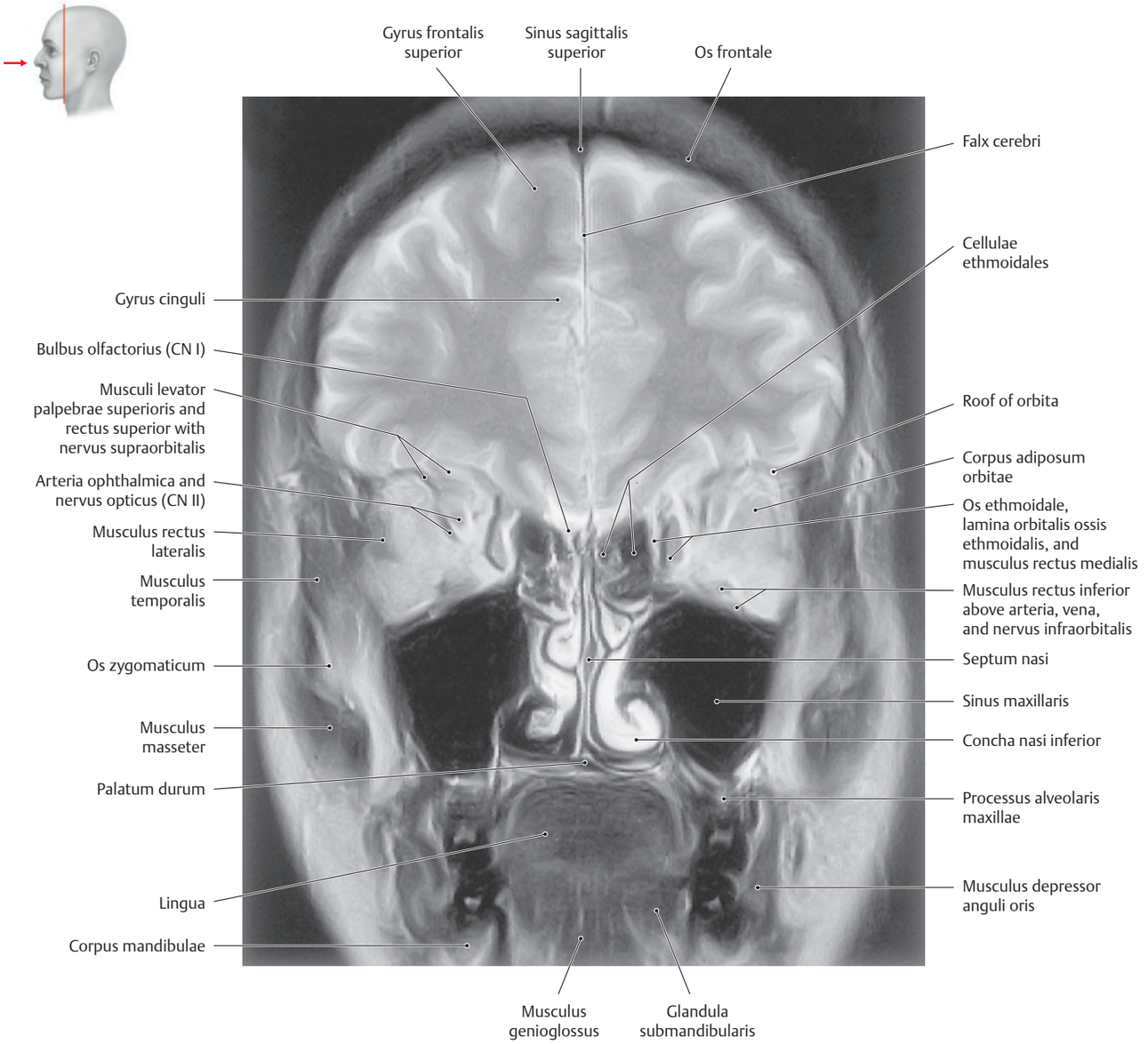


Fig. 14.6 **Coronal MRI through the posterior orbita**
Anterior view. The inferior margin of the falx cerebri is now superior to the gyrus cinguli. In the orbit, the nervus supraorbitalis runs with the musculi levator palpebrae superioris and rectus superior, and the nervus oculomotorius (CN III) runs lateral to the musculus rectus inferior, which in turn runs superior to the canalis infraorbitalis. The arteria ophthalmica can be used to find the more medially located nervus opticus (CN II), both of which emerge from the canalis opticus. Note the asymmetrical nature of the cavitates nasi. The glandula submandibularis is more prominent in this section between the musculus genioglossus and the corpus mandibulae.

Coronal MRIs of the Neck (I): Anterior

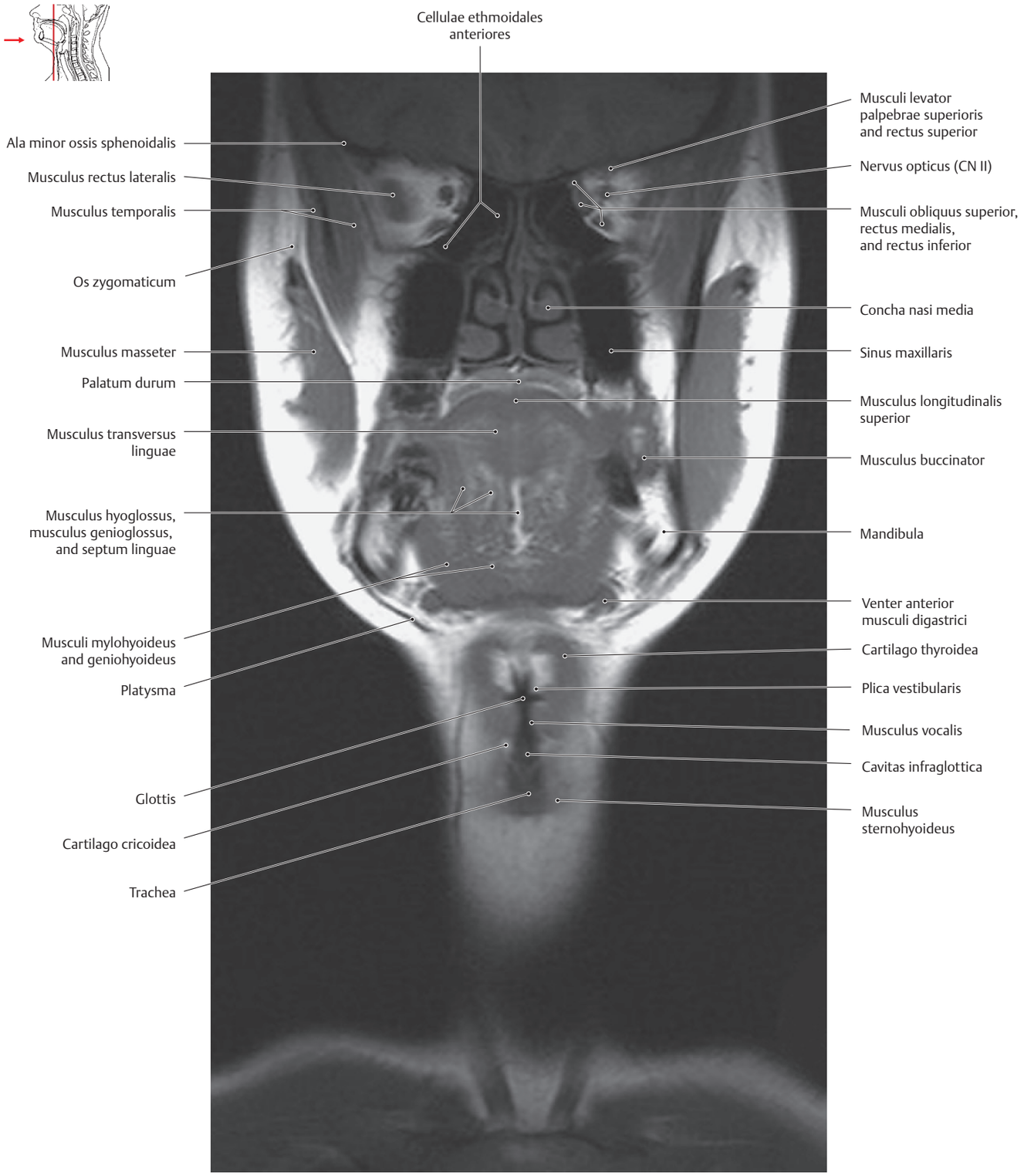


Fig. 14.7 **Coronal MRI of the musculi linguae**
Anterior view. This plane of section lies just posterior to the previous one and transects the extrinsic lingual muscles (musculi genioglossus and hyoglossus) and intrinsic lingual muscles (musculi longitudinalis and transversus). The musculi masticatorii (musculi temporalis and masseter) are visible, as are the musculi buccinator, mylohyoideus, and geniohyoideus. This section cuts the larynx and trachea, revealing the plica vestibularis, musculus vocalis, and cartilago cricoidea.

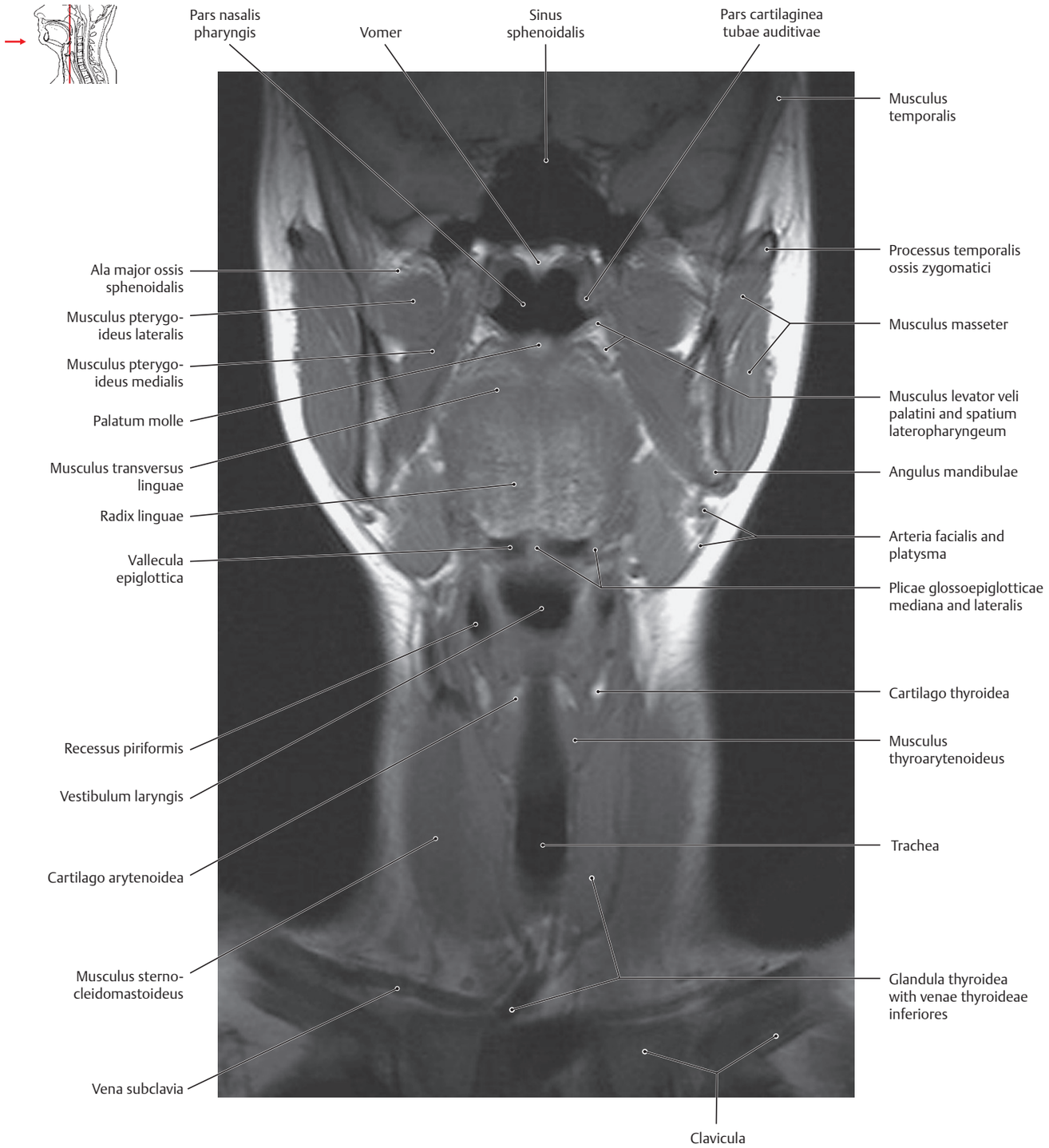


Fig. 14.8 **Coronal MRI of the palatum molle and musculi masticatorii**

Anterior view. This section illustrates the convergence of the air- and foodways in the pharynx. The pars nasalis pharyngis lies inferior to the sinus sphenoidalis and superior to the palatum molle. It converges with the foodway in the pars oralis pharyngis, located posterior to the uvula (not shown). The pars oralis pharyngis continues inferiorly to the epiglottis (the vallecula epiglottica lies anterior to this). The air- and foodways then diverge into the larynx and pars laryngea pharyngis, respectively. The vestibulum laryngis is the superior portion of the larynx, above the plicae vocales. This section reveals the cartilagines thyroidea and arytenoideae of the larynx. Compare this image to **Fig. 14.9**.

Coronal MRIs of the Neck (II)

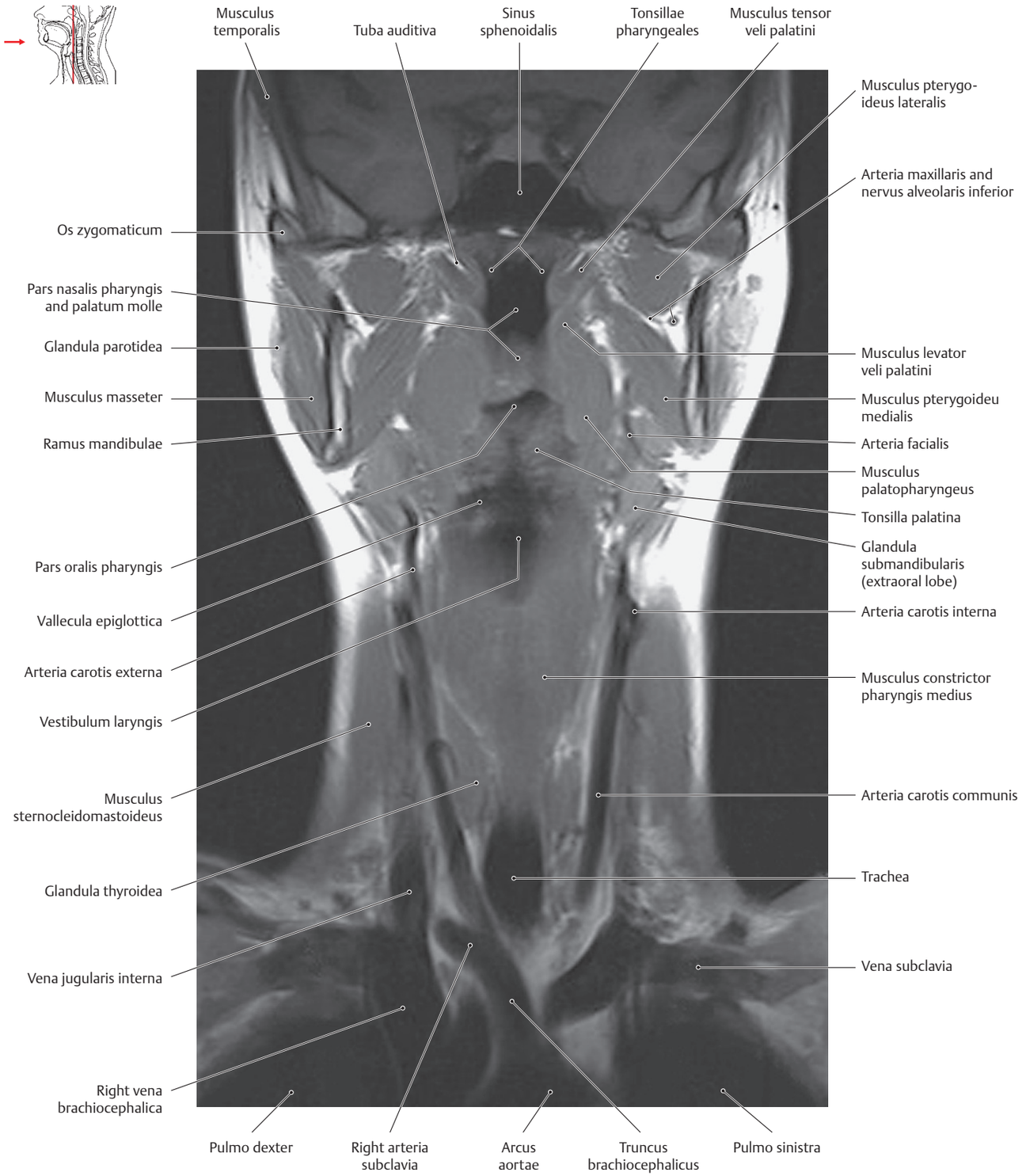


Fig. 14.9 **Coronal MRI of the great vessels**
Anterior view. This image clearly demonstrates the course of the great vessels in the neck. This image is also an excellent demonstration of the structures of the cavitas oris. Note the position of the tonsillae pharyngeales on the roof of the pars nasalis pharyngis and the extent of the tonsillae palatinae in the pars oralis pharyngis.

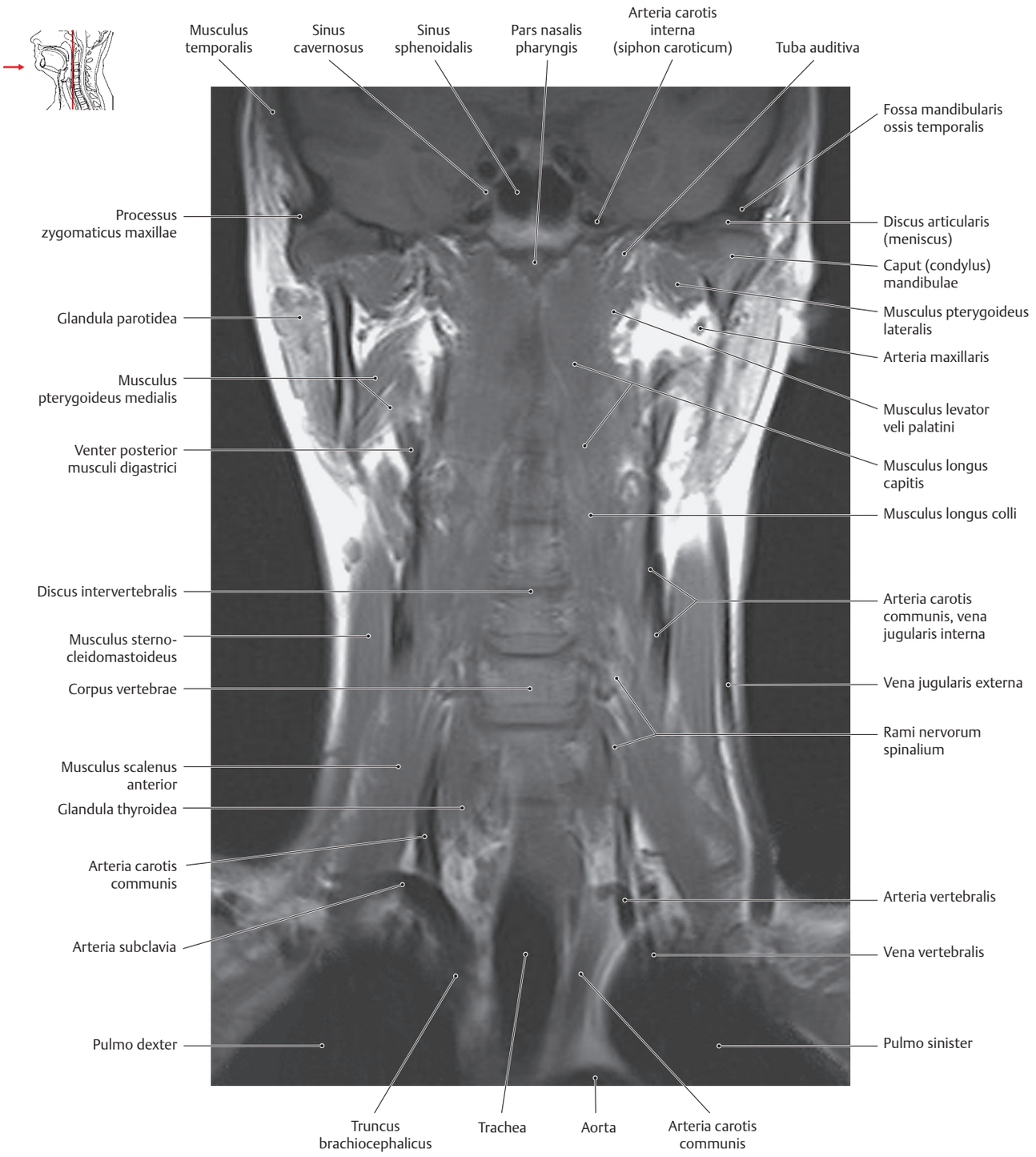


Fig. 14.10 **Coronal MRI through the articulatio temporomandibularis (TMJ)**

Anterior view. This image clearly demonstrates the structures of the TMJ, in particular the discus articularis and caput mandibulae. The ramus mandibulae is seen medial to the glandula parotidea. This image shows the vertebrae cervicales with disci intervertebrales.

Coronal MRIs of the Neck (III): Posterior

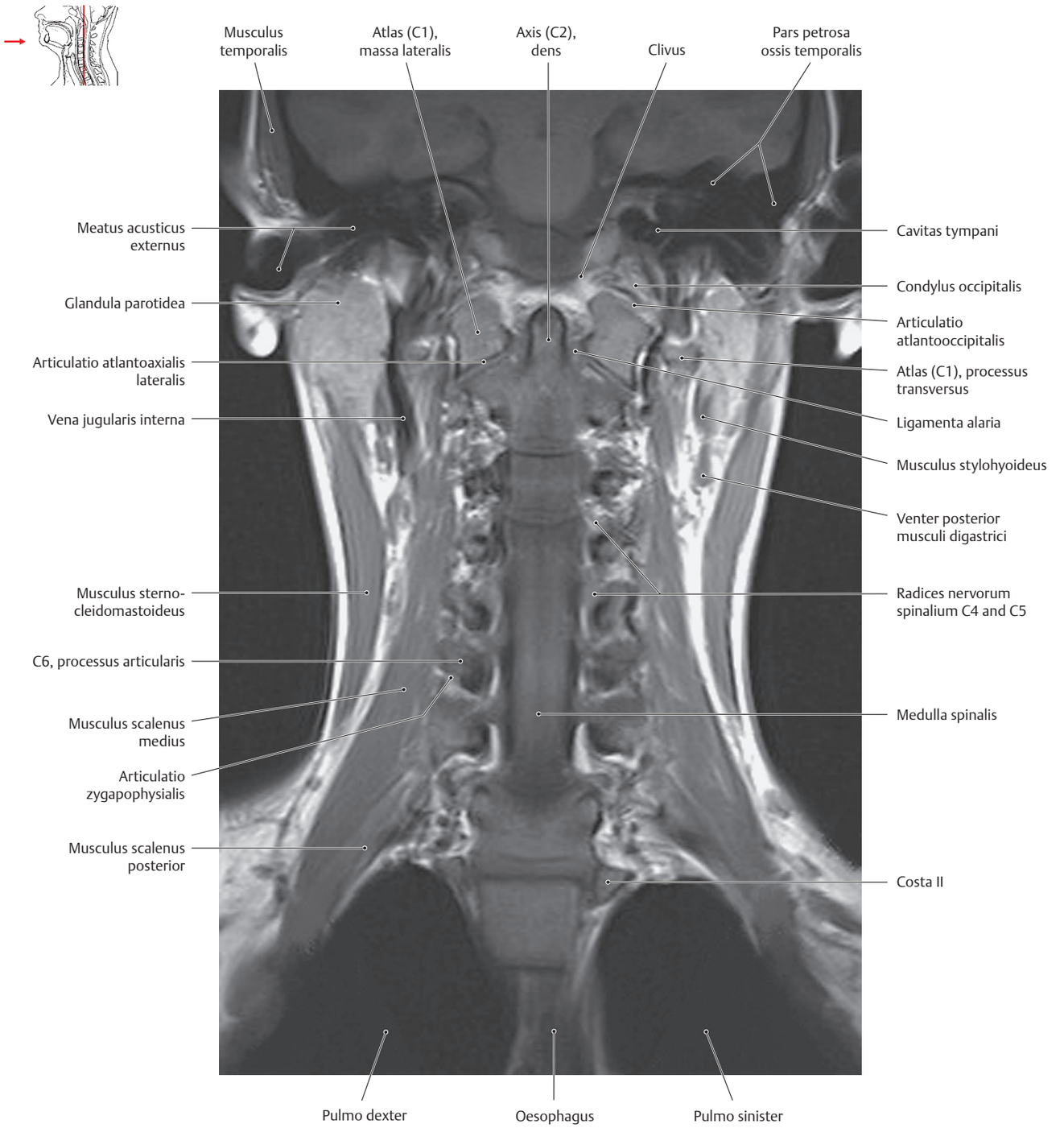


Fig. 14.11 **Coronal MRI through the vertebrae cervicales and nervi spinales**

Anterior view. This image clearly shows the C1 through T2 vertebrae. The massae laterales of the atlas (C1) can be seen flanking the dens of the axis (C2). The more inferior vertebrae can be counted using the processus articulares of the cervical vertebrae. The radices nervorum spinalium emerge between the processus articulares (note for counting purposes: the C3 radix emerges inferior to C2 and superior to the processus articulares of C3).

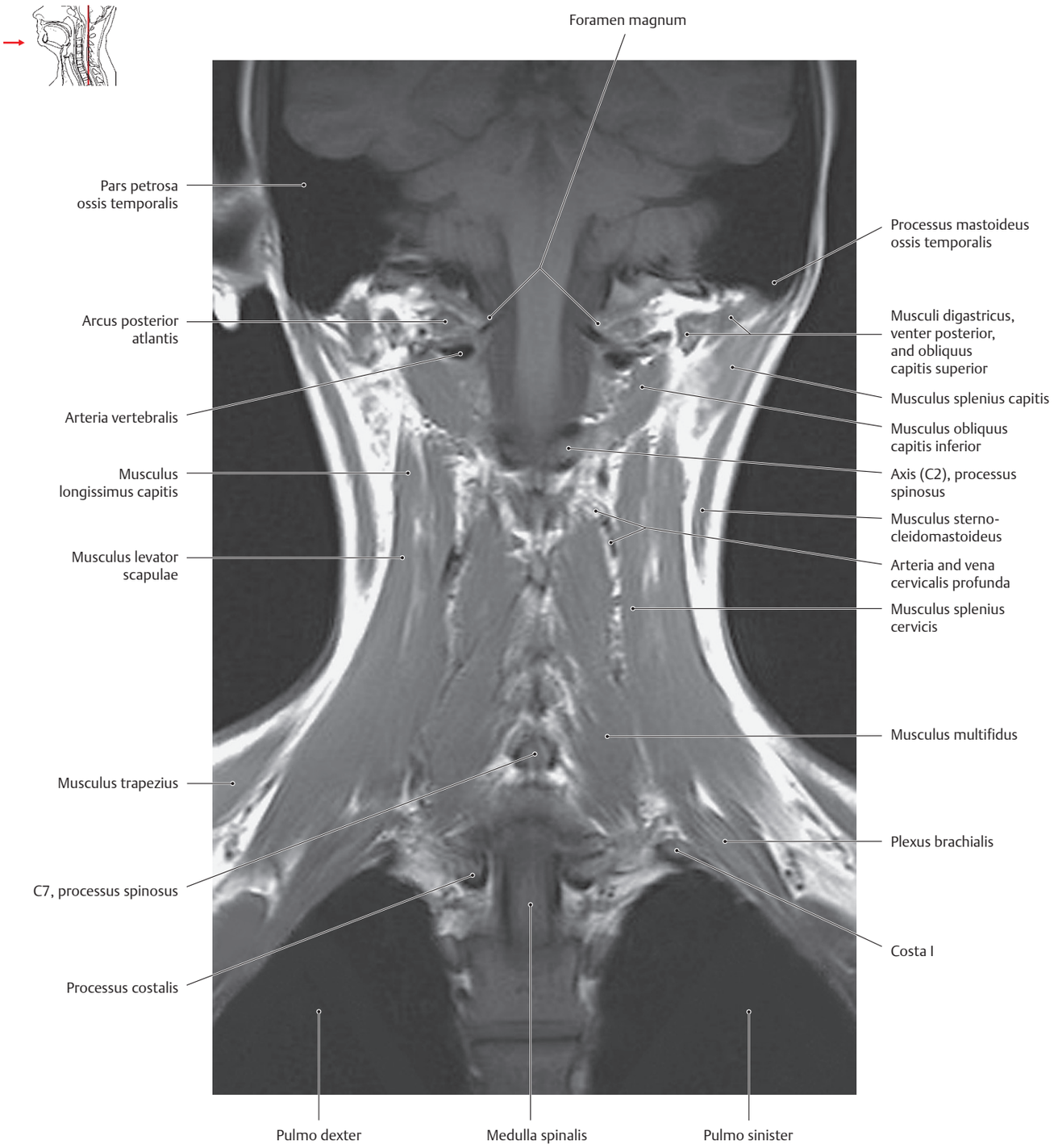


Fig. 14.12 **Coronal MRI through the nuchal muscles**
Anterior view. This image clearly shows the relations of the muscles in the neck. *Note:* The elongated processus spinosus of the C7 vertebra (vertebra prominens) is still visible in this section. The medulla spinalis is visible both during its passage through the foramen magnum and more caudally, posterior to the T1 corpus vertebrae.

Transverse Sections of the Head (I): Cranial

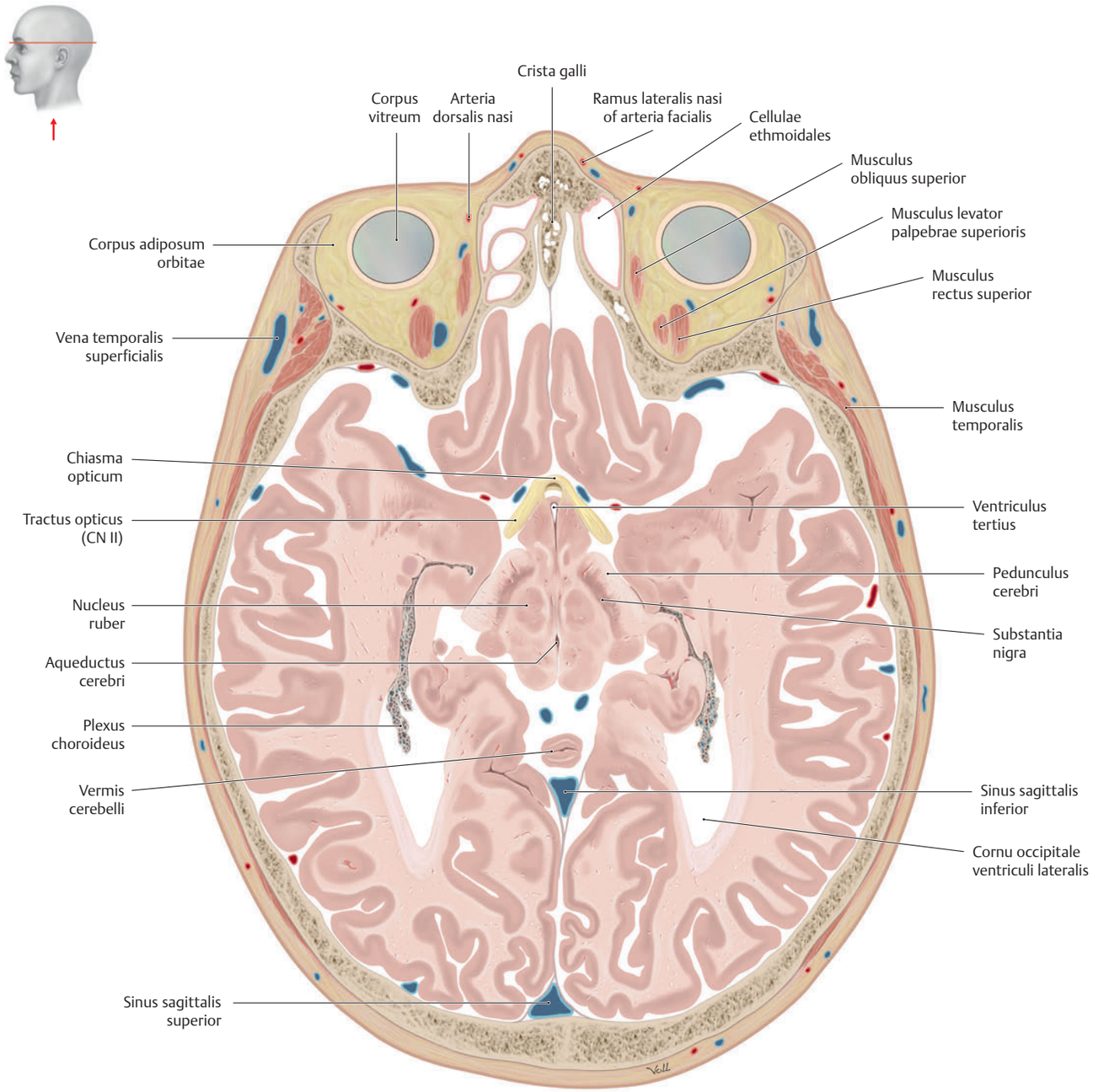


Fig. 14.13 **Transverse section through the upper level of the orbitae**

Inferior view. The highest section in this series displays the muscles in the upper level of the orbita (the orbital levels are described on p. 236). The section cuts the bony crista galli in the fossa cranii anterior, flanked on each side by cells of the sinus ethmoidalis. The sections of the chiasma opticum and adjacent tractus opticus are parts of the diencephalon, which surrounds the ventriculus tertius at the center of the section. The nucleus ruber and substantia nigra are visible in the mesencephalon. The tractus pyramidalis descends in the pedunculi cerebri. The section passes through the cornua posteriora (occipitalia) of the ventriculi laterales and barely cuts the vermis of the cerebellum in the midline.

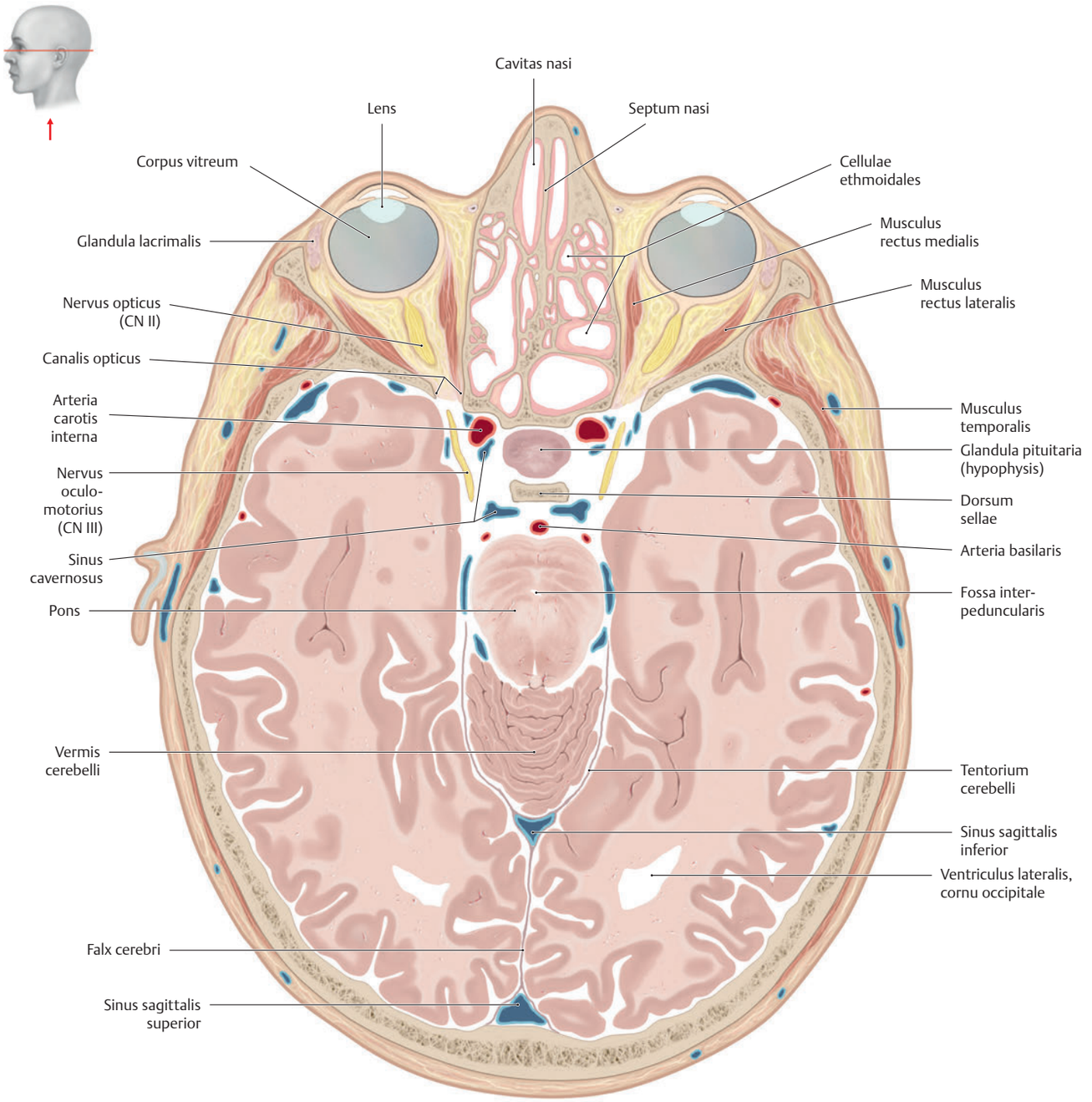


Fig. 14.14 **Transverse section through the nervus opticus and hypophysis**

Inferior view. The nervus opticus is seen just before its entry into the canalis opticus, indicating that the plane of section passes through the middle level of the orbita. Because the nerve completely fills the canal, growth disturbances of the bone at this level may cause pressure injury to the nerve. This plane cuts the lentes and the cellulae labyrinthi ethmoidalis. The arteria carotis interna can be identified in the fossa cranii media, embedded in the sinus cavernosus. The section cuts the nervus oculomotorius on either side, which courses in the lateral wall of the sinus cavernosus. The pons and vermis cerebelli are also seen. The falx cerebri and tentorium cerebelli appear as thin lines that come together at the sinus rectus.

Transverse Sections of the Head (II)

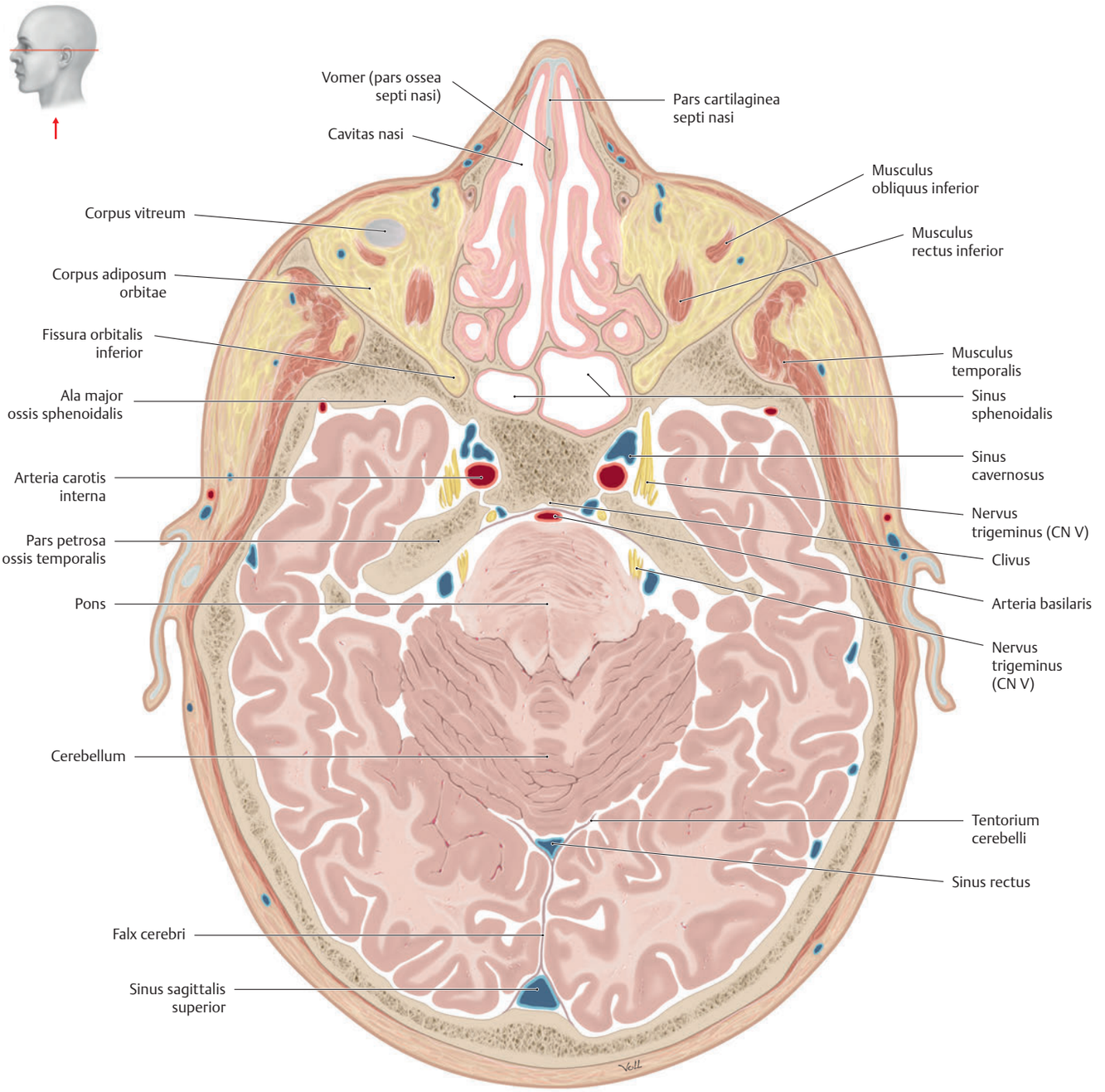


Fig. 14.15 **Transverse section through the sinus sphenoidalis**
Inferior view. This section cuts the fossa infratemporalis on the lateral aspect of the skull and the musculus temporalis that lies within it. The plane passes through the lower level of the orbita, which is continuous posteriorly with the fissura orbitalis inferior. This section displays the anterior extension of the two alae majores of the os sphenoidale and the posterior extension of the two partes petrosae of the ossa temporalia, which mark the boundary between the fossae cranii media and posterior. The clivus is part of the fossa cranii posterior and lies in contact with the arteria basilaris. The pontine origin of the nervus trigeminus is visible. *Note:* The nervus trigeminalis passes superior to the pars petrosa ossis temporalis to enter the fossa cranii media.

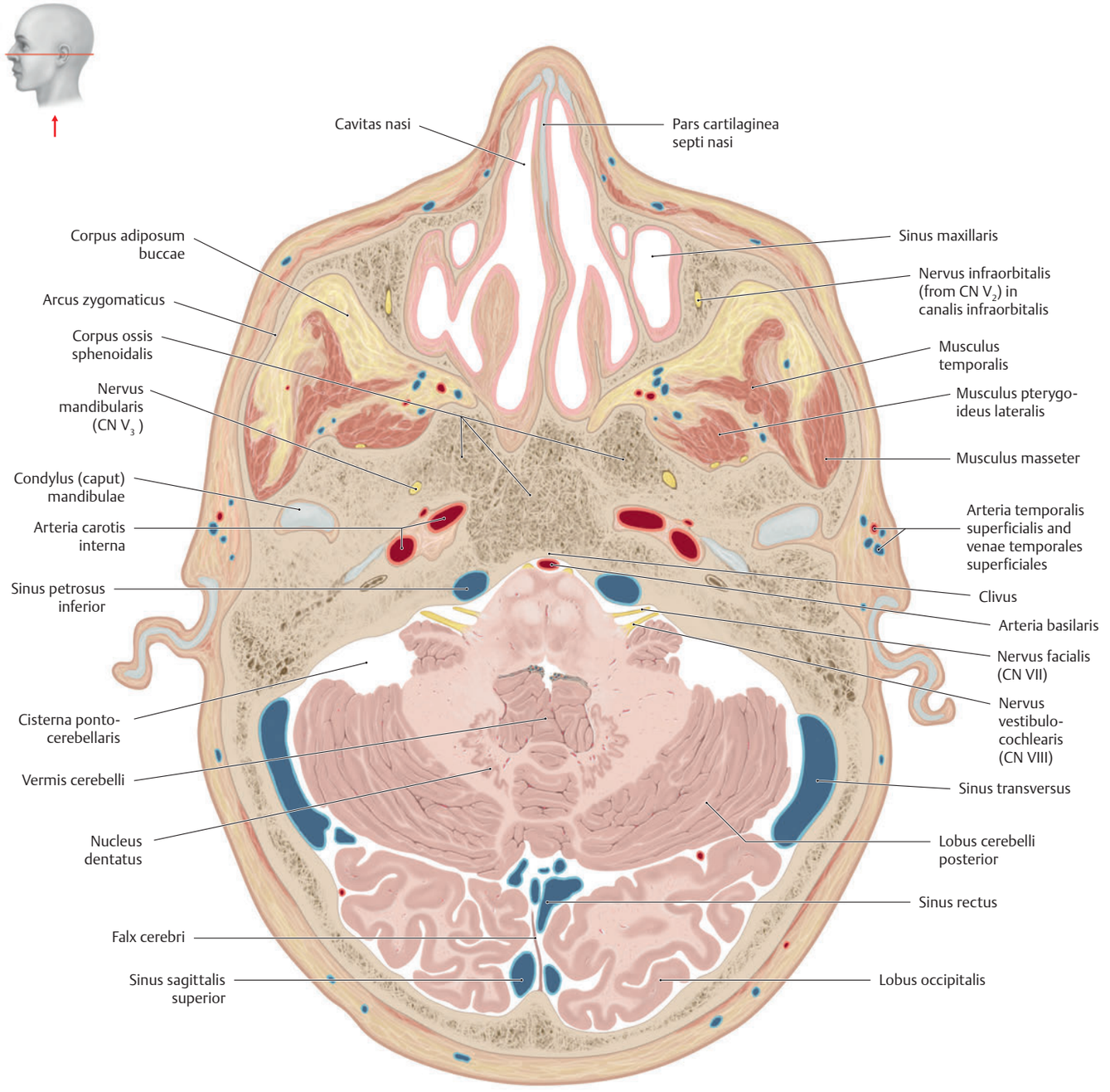


Fig. 14.16 **Transverse section through the concha nasi media**
Inferior view. This section below the orbita passes through the nervus and canalis infraorbitalis. Medial to the nervus infraorbitalis is the roof of the sinus maxillaris. The arcus zygomaticus is visible in its entirety, with portions of the musculi masticatorii (musculi masseter, temporalis, and pterygoidea lateralis) and the upper part of the caput mandibulae. The nervus mandibularis division of the nervus trigeminus (CN V_3) appears in cross-section in its bony canal, the foramen ovale. The corpus ossis sphenoidalis forms the bony center of the base of the skull. The nervi facialis and vestibulocochlearis (CNs VII and VIII) emerge from the truncus encephali and enter the meatus acusticus internus. The nucleus dentatus lies within the substantia alba cerebelli. The space around the anterior part of the cerebellum, the cisterna pontocerebellaris, is filled with liquor cerebrospinalis in the living individual. The sinus transversus is prominent among the dural sinuses of the brain.

Transverse Sections of the Head (III): Caudal

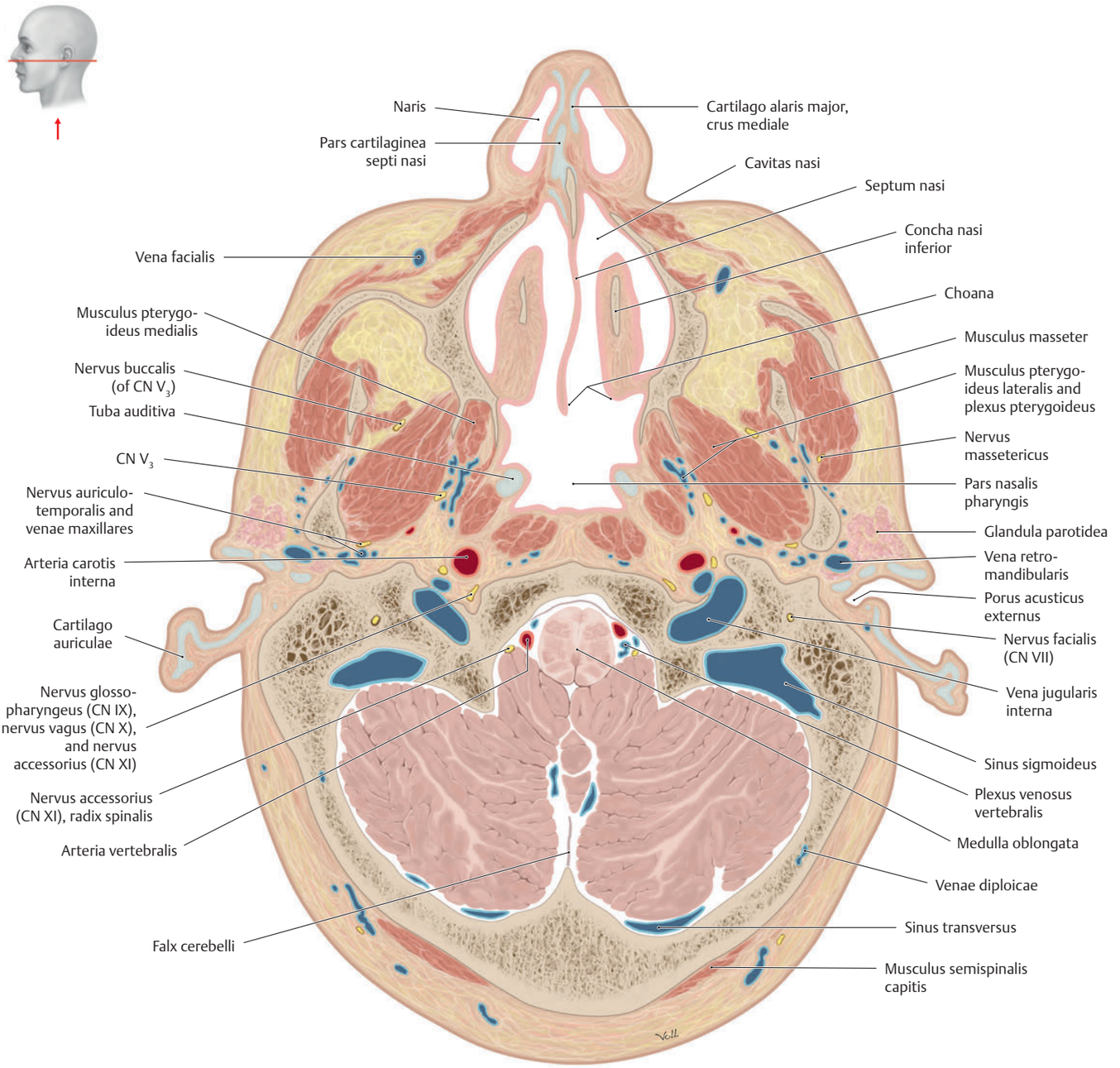


Fig. 14.17 **Transverse section through the pars nasalis pharyngis**
Inferior view. This section passes through the external nose and portions of the cartilaginous nasal skeleton. The cavitates nasi communicate with the pars nasalis pharyngis through the choanae. Cartilaginous portions of the tuba auditiva project into the pars nasalis pharyngis. The vena jugularis interna travels with the nervus vagus (CN X) and arteria carotis commune as a neurovascular bundle within the vagina carotica, a fascial covering that extends from the base of the skull to the arcus aortae. The nervi glossopharyngeus, accessorius, and hypoglossus (CN IX, XI, and XII) also pierce the upper portion of the vagina carotica. However, these neurovascular structures do not all enter and exit the skull base together. The foramen jugulare consists of a neural and a venous portion. The neural portion conducts the nervi glossopharyngeus (CN IX), vagus (CN X), and accessorius (CN XI), and the venous portion contains the bulbus superior venae jugularis, which receives blood from the sinus sigmoideus. (*Note:* The vena jugularis interna begins at the inferior portion of the foramen jugulare.) The arteria carotis interna enters the canalis caroticus, and the nervus hypoglossus (CN XII) enters the canalis nervi hypoglossi.

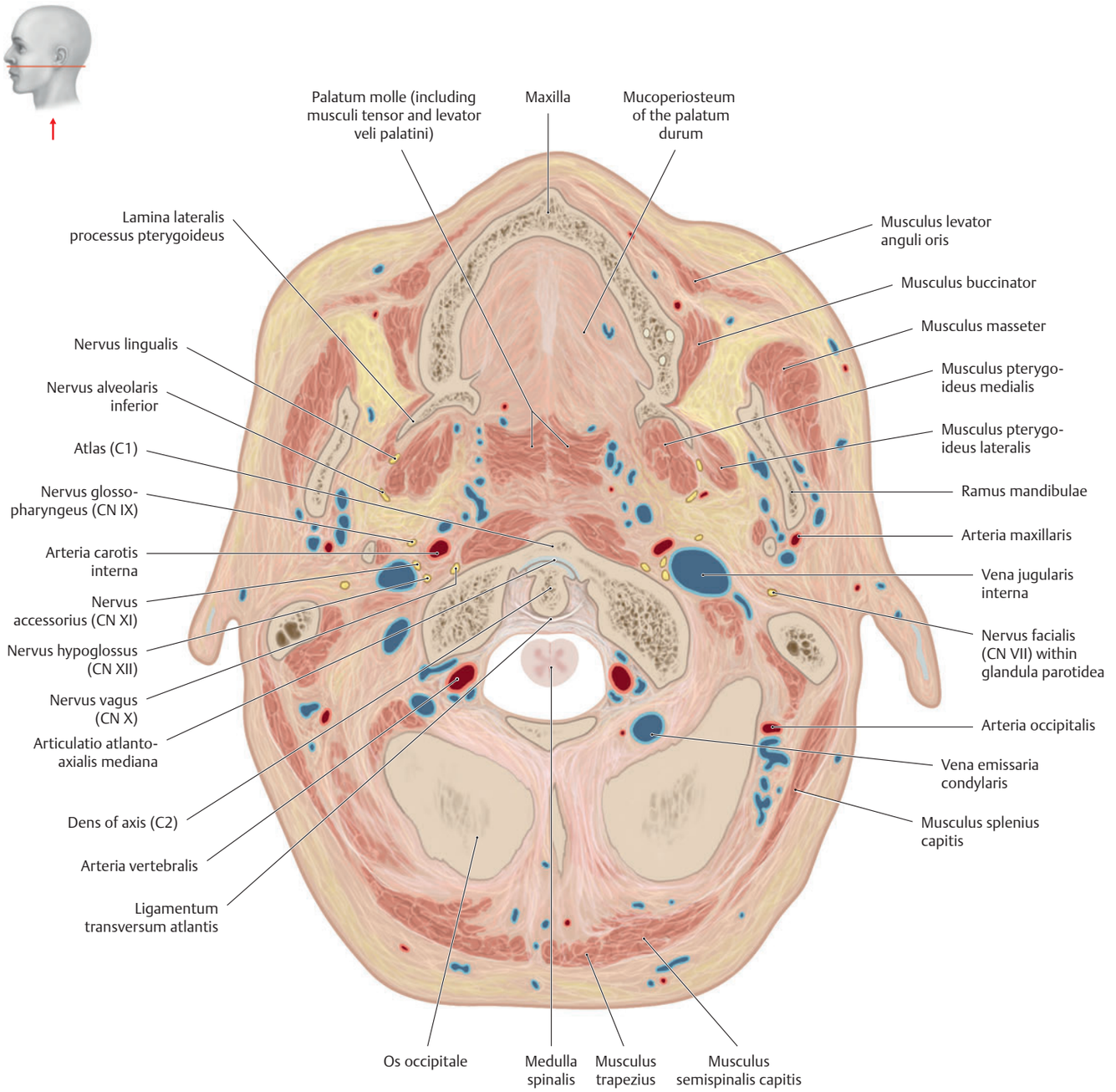


Fig. 14.18 **Transverse section through the articulatio atlantoaxialis mediana**

Inferior view. The section at this level passes through the connective tissue sheet that stretches over the bone of the palatum durum. Portions of the upper pharyngeal muscles are sectioned close to their origin. The neurovascular structures in the vagina carotica are also well displayed. The dens of the axis articulates in the articulatio atlantoaxialis mediana with the facet for the dens on the posterior surface of the arcus anterior atlantis. The ligamentum transversum atlantis that helps to stabilize this joint can also be identified. The arteria vertebralis and its accompanying veins are displayed in cross-section, as is the medulla spinalis. In the occipital region, the section passes through the upper portion of the posterior neck muscles.

Transverse Sections of the Neck (I): Cranial

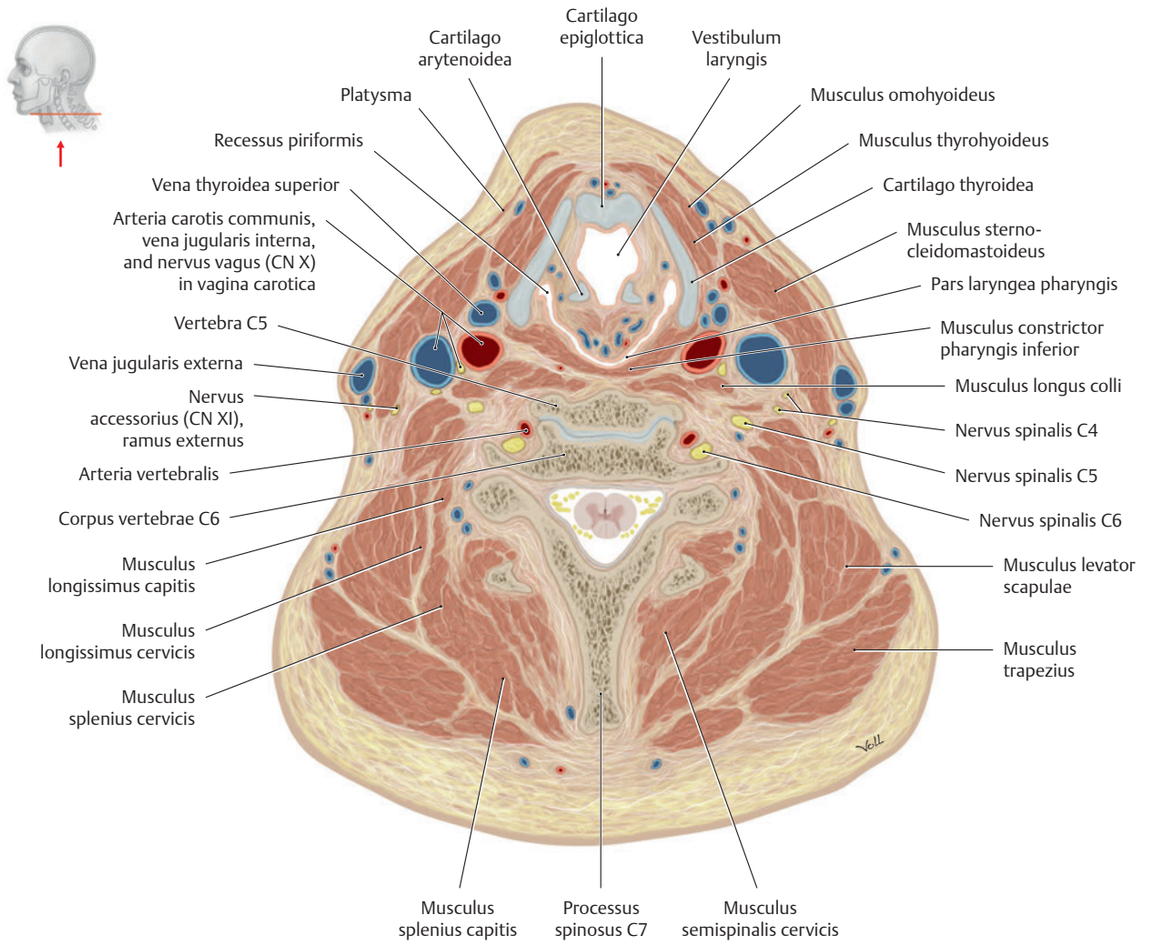


Fig. 14.19 **Transverse section at the level of the corpus vertebrae C5**

Inferior view. The vena jugularis interna travels with the arteria carotis communis and nervus vagus in the vagina carotica. The nervus accessorius (CN XI) is medial to the musculus sternocleidomastoideus; more proximal to the skull base it will pierce the vagina carotica to enter the foramen jugulare with the vena jugularis interna, as well as CN IX and X. The elongated processus spinosus of the vertebra C7 (vertebra prominens) is visible at this level, owing to the lordotic curvature of the neck. Note that the triangular shape of the cartilago arytenoidea is clearly demonstrated in the laryngeal cross-section.

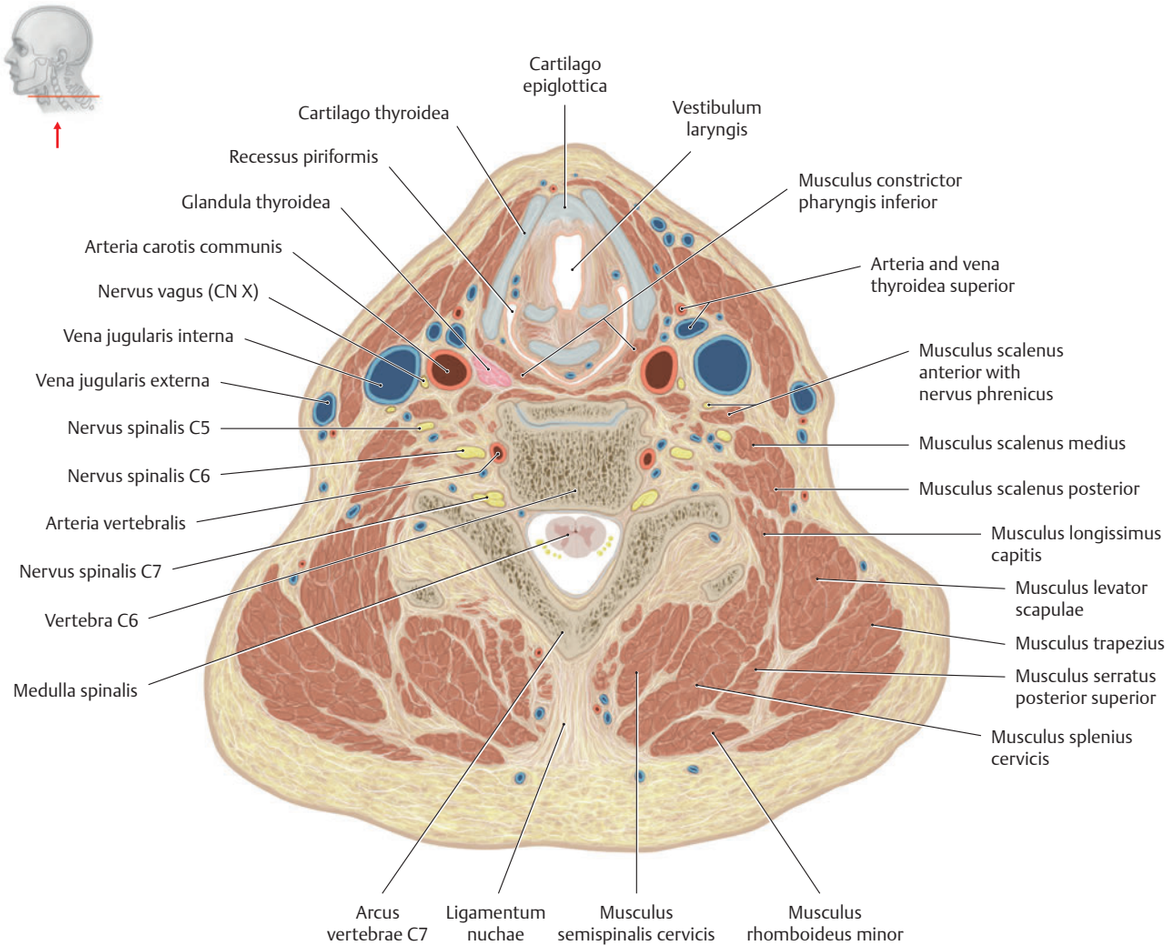


Fig. 14.20 **Transverse section through the corpus vertebrae C6**
Inferior view. The recessus piriformis can be identified at this level, and the arteria vertebralis is visible in its course along the corpus vertebrae. The nervus vagus (CN X) lies in a posterior angle between the arteria carotis commune and vena jugularis interna within the vagina carotica. The nervus phrenicus, which arises from the rami anteriores of nervi spinales C3–C5, lies on the musculus scalenus anterior on the left side.

Transverse Sections of the Neck (II): Caudal

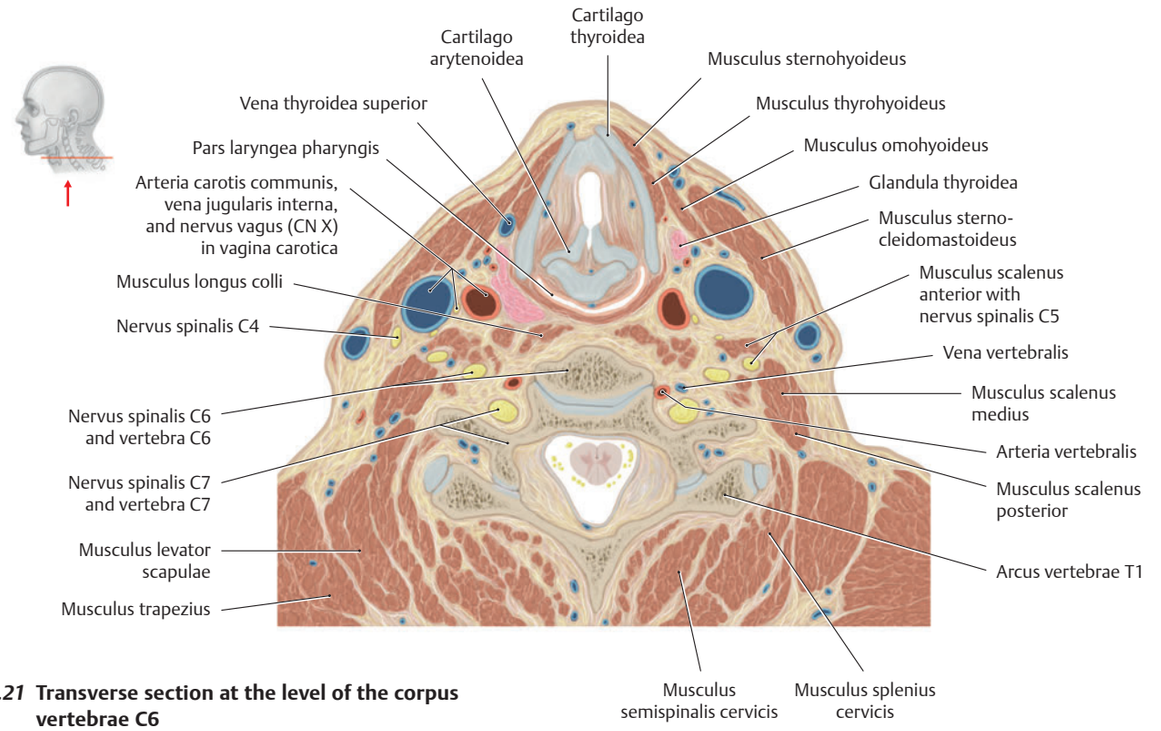


Fig. 14.21 **Transverse section at the level of the corpus vertebrae C6**

Inferior view. This cross-section passes through the base of the cartilago arytenoidea in the larynx. The pars laryngea pharyngis appears as a narrow transverse cleft behind the larynx.

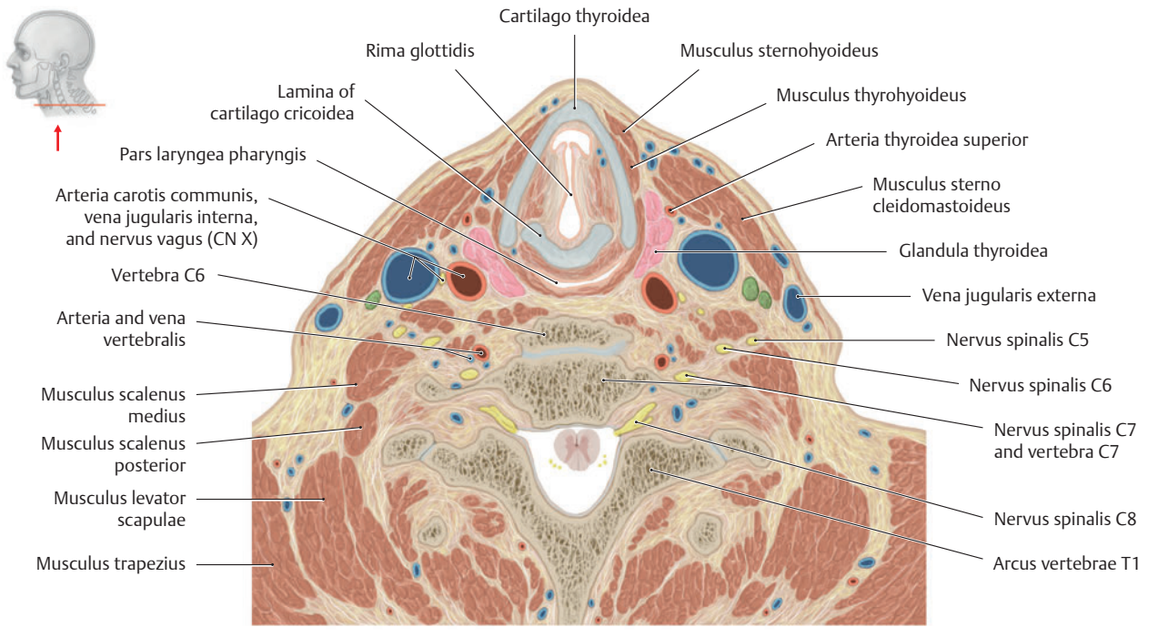


Fig. 14.22 **Transverse section at the level of the C6/C7 vertebral junction**

Inferior view. This cross-section passes through the larynx at the level of the plicae vocales. The glandula thyroidea appears considerably smaller at this level than in subsequent views.

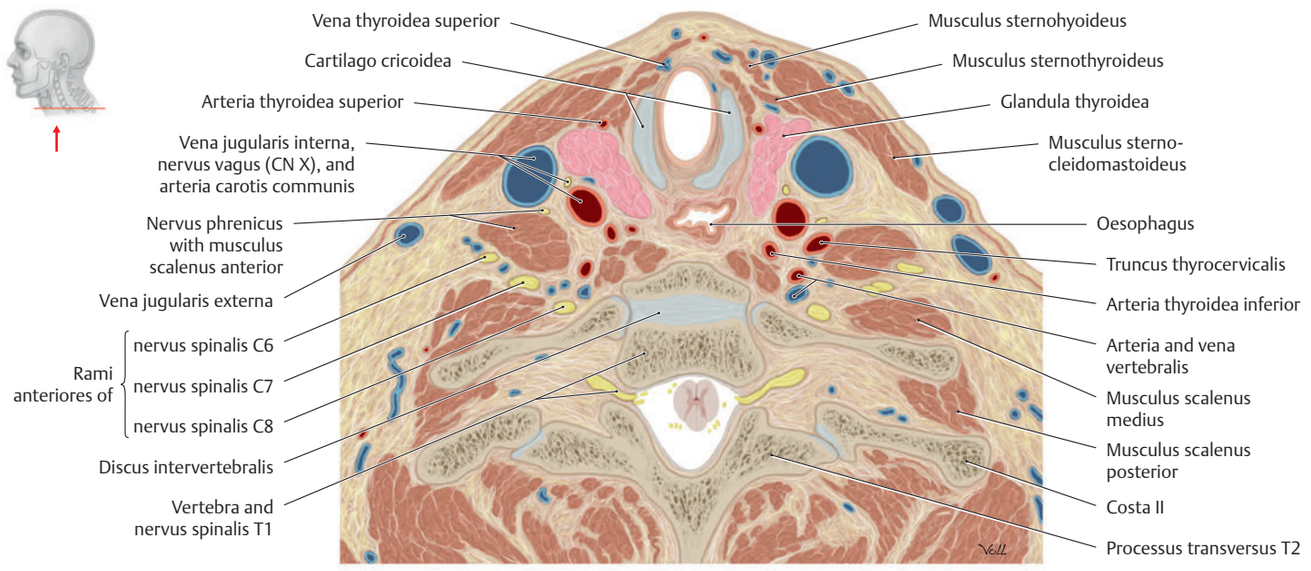


Fig. 14.23 **Transverse section at the level of the C7/T1 vertebral junction**

Inferior view. This cross-section clearly displays the musculi scaleni anterior and medius and the interval between them, which is traversed by the radices C6–C8 of the plexus brachialis. Note the neurovascular structures (arteria carotis communis, vena jugularis interna, nervus vagus) that lie within the vagina carotica between the musculus sterno-cleidomastoideus, musculus scalenus anterior, and glandula thyroidea.

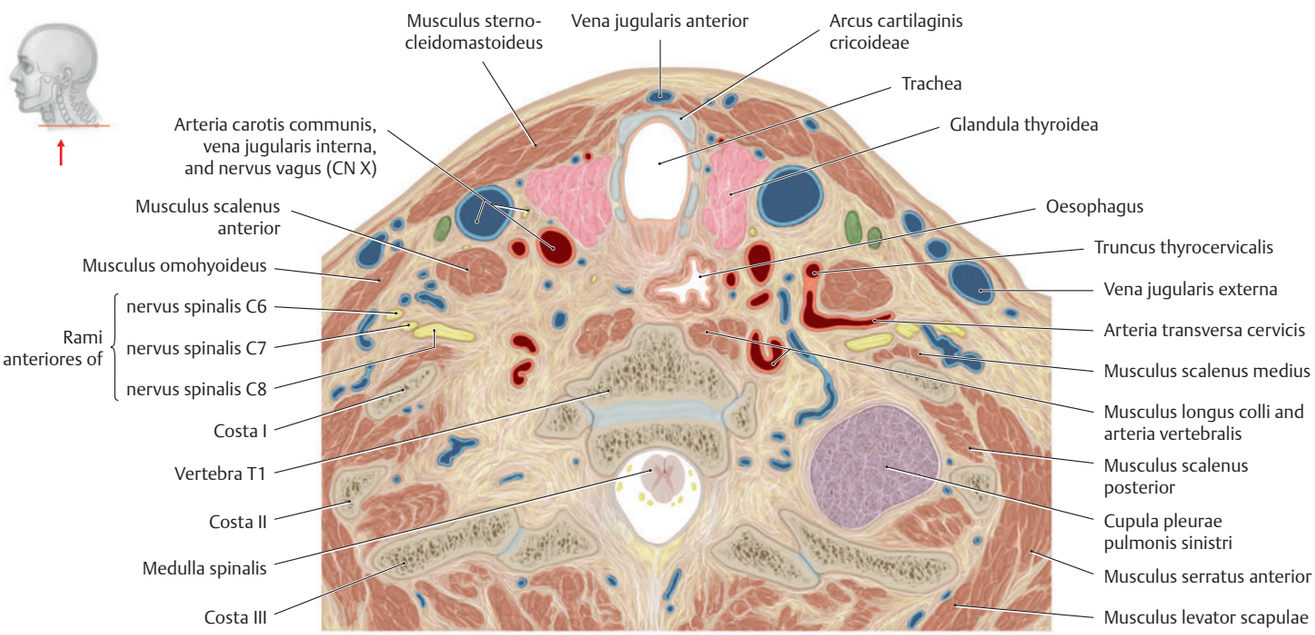
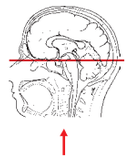
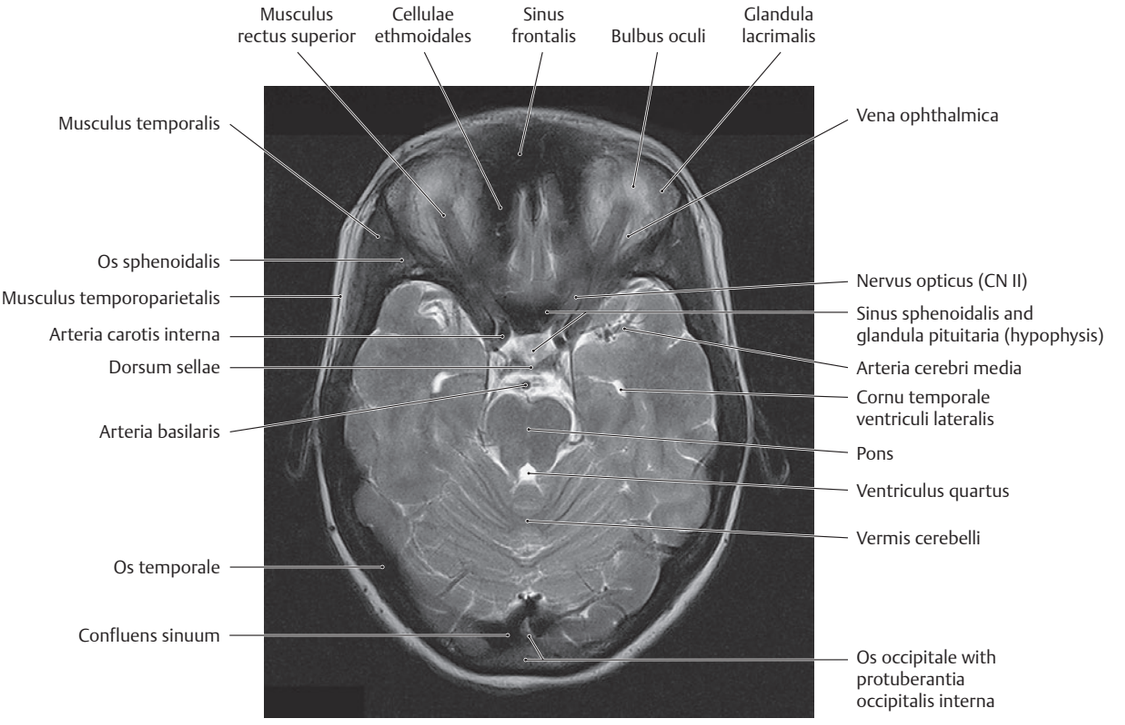


Fig. 14.24 **Transverse section at the level of the T1/T2 vertebral junction**

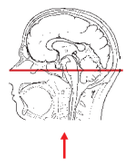
Inferior view. Due to the curvature of the neck in this specimen, the section also cuts the discus intervertebralis between T1 and T2. This section includes the radices nervorum spinalium C6–C8 of the plexus brachialis and a small section of the left cupula pleurae. The proximity of the apex pulmonis to the plexus brachialis shows why the growth of an apical lung tumor may damage the radices plexus brachialis. Note also the glandula thyroidea and its proximity to the trachea and neurovascular bundle in the vagina carotica.

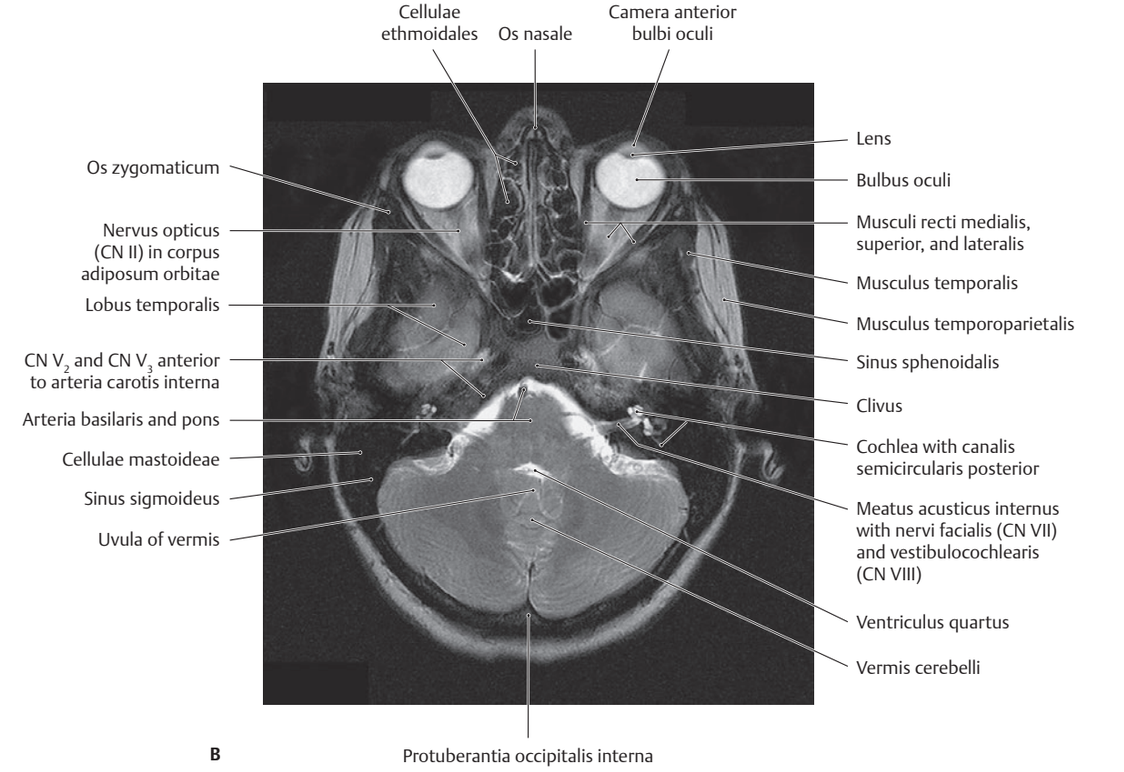
Transverse MRIs of the Head





A





B

Fig. 14.25 **Transverse MRIs through the orbita and cellulae ethmoidales**

Inferior view. **A** Superior orbita. This section demonstrates the relationship of the sinus frontalis and sphenoidalis to the orbita and cavitas nasi. **B** Section through nervus opticus (CN II). The divisions of the eye can be clearly seen along with the extraocular muscles located in the corpus adiposum orbitae. The sinus sigmoideus is located posterior to the cellulae mastoideae and lateral to the cerebellum. This section clearly displays the meatus acusticus internus, which conducts the nervi facialis (CN VII) and vestibulocochlearis (CN VIII).

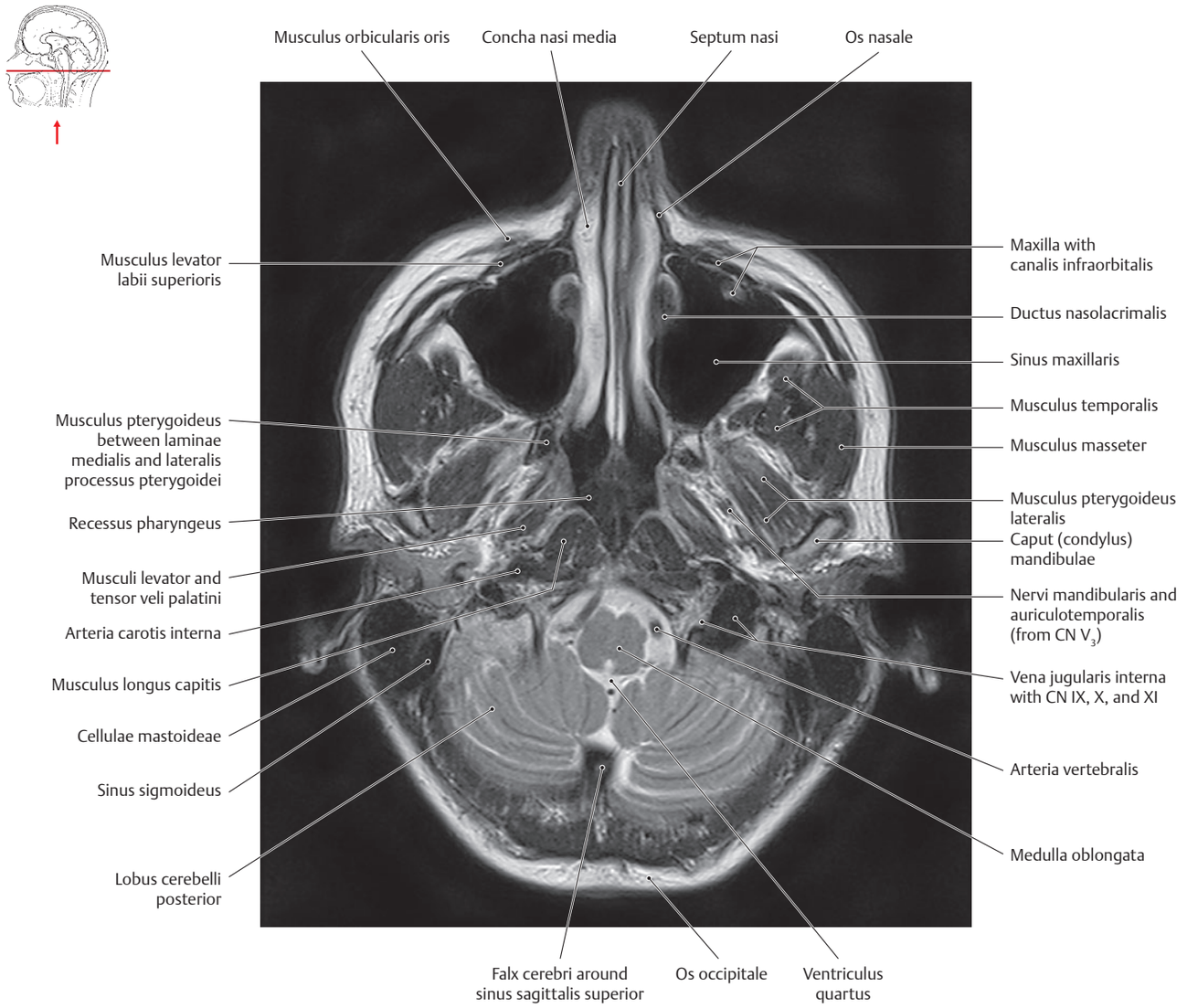


Fig. 14.26 **Transverse MRI through the sinus maxillaris and ductus nasolacrimalis**

Inferior view. This section clearly demonstrates the relationships of the canalis infraorbitalis and ductus nasolacrimalis to the sinus maxillaris. The laminae medialis and lateralis processus pterygoidei can be seen flanking the musculus pterygoideus medialis. The recessus pharyngeus is visible, anterior to the musculus longus capitis. The nervus mandibularis division of the nervus trigeminus (CN V_3) is lateral to the musculi levator and tensor veli palatini and medial to the musculus pterygoideus lateralis. The nervi glossopharyngeus, vagus, and accessorius (CN IX, X, and XI) run just anteromedial to the vena jugularis interna.

Transverse MRIs of the Cavitas Oris

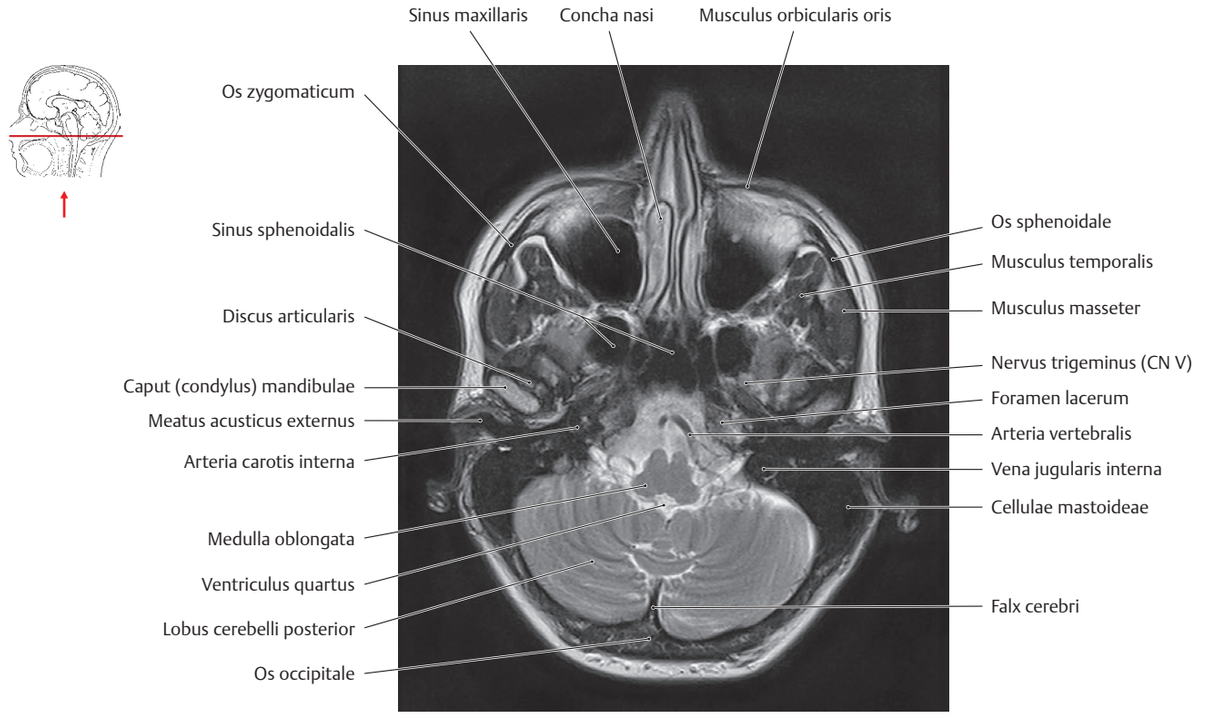


Fig. 14.27 **Transverse MRI through the articulatio temporomandibularis (TMJ)**
Inferior view. *Note:* The plane of this section is slightly higher than **Fig. 14.26**. It has been included here in order to show the discus articularis of the TMJ and the full extent of the mandibula.

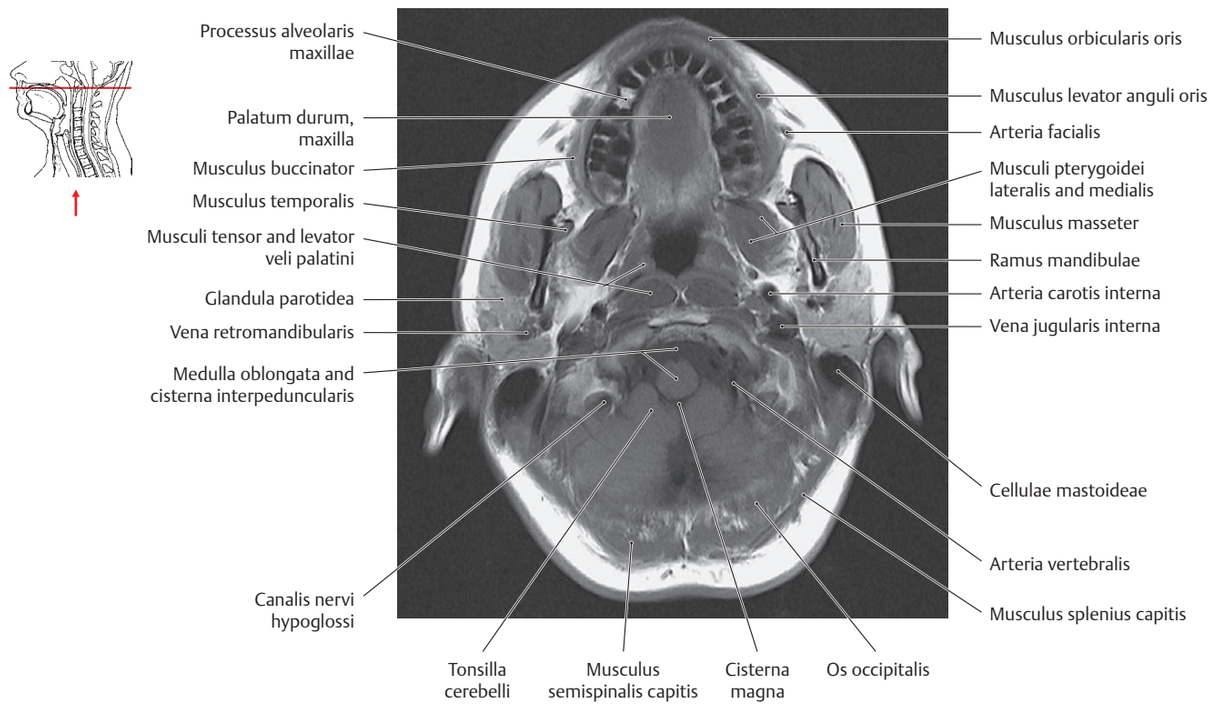
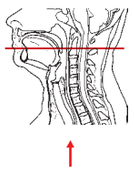
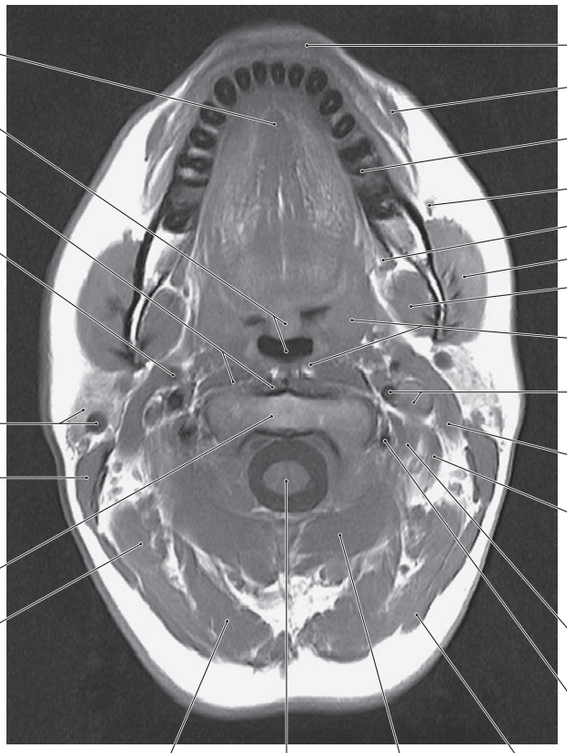
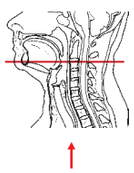


Fig. 14.28 **Transverse MRI through the palata durum and molle**
Inferior view. This section demonstrates the relation of the ramus mandibulae to the musculi masticatorii in the fossa infratemporalis.





A



B

Fig. 14.29 **Transverse MRIs through the mandibula**
Inferior view. **A** Section through arcus dentalis mandibularis. This section demonstrates the relationship of the pars oralis pharyngis to the palatum molle (uvula) and prevertebral muscles (musculi longus colli and capitis). The vessels of the vagina carotica are clearly visible, along with the vena retromandibularis in the glandula parotidea. **B** Section through corpus mandibulae and pars laryngea pharyngis.

Transverse MRIs of the Neck

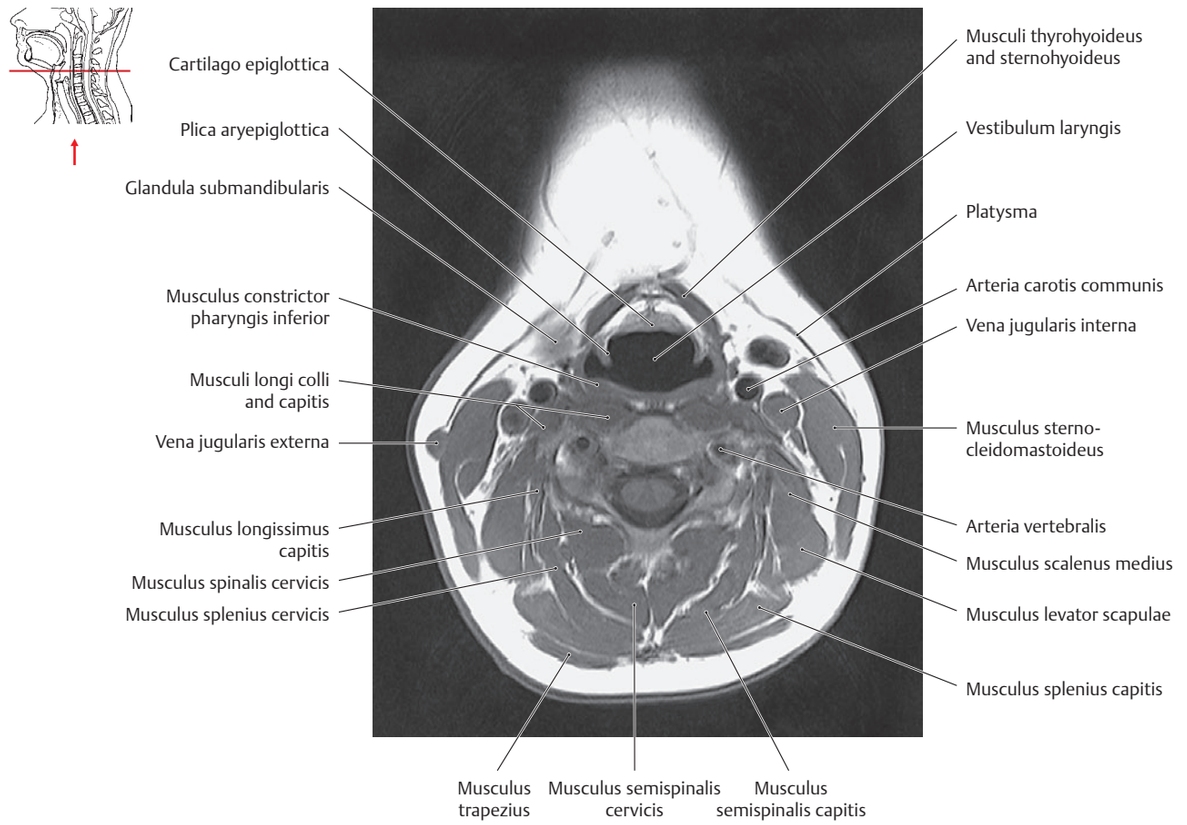


Fig. 14.30 **Transverse MRI through the corpus vertebrae C4**
Inferior view. This section demonstrates the plica aryepiglottica in the vestibulum laryngis. Note the proximity of the prevertebral muscles to the pharyngeal constrictors.

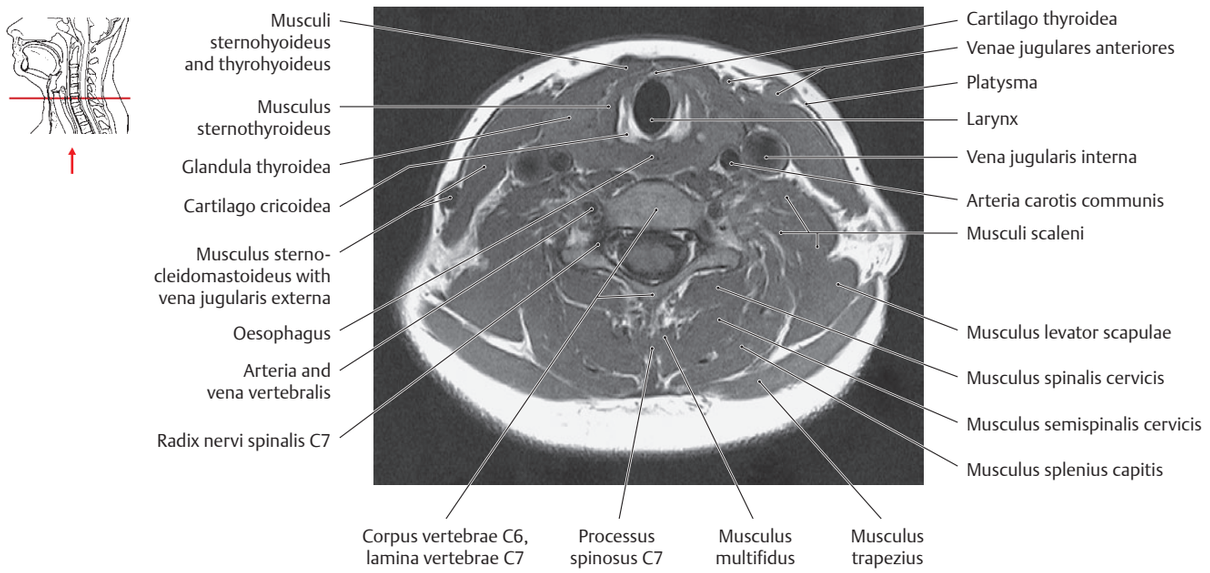


Fig. 14.31 **Transverse MRI through the corpus vertebrae C6**
Inferior view. This section demonstrates the cartilagines cricoidea and thyroidea of the larynx (note the change in shape of the larynx). Due to lordosis of the cervical spine, this section includes the corpus vertebrae C6 and the processus spinosus C7 with lamina.

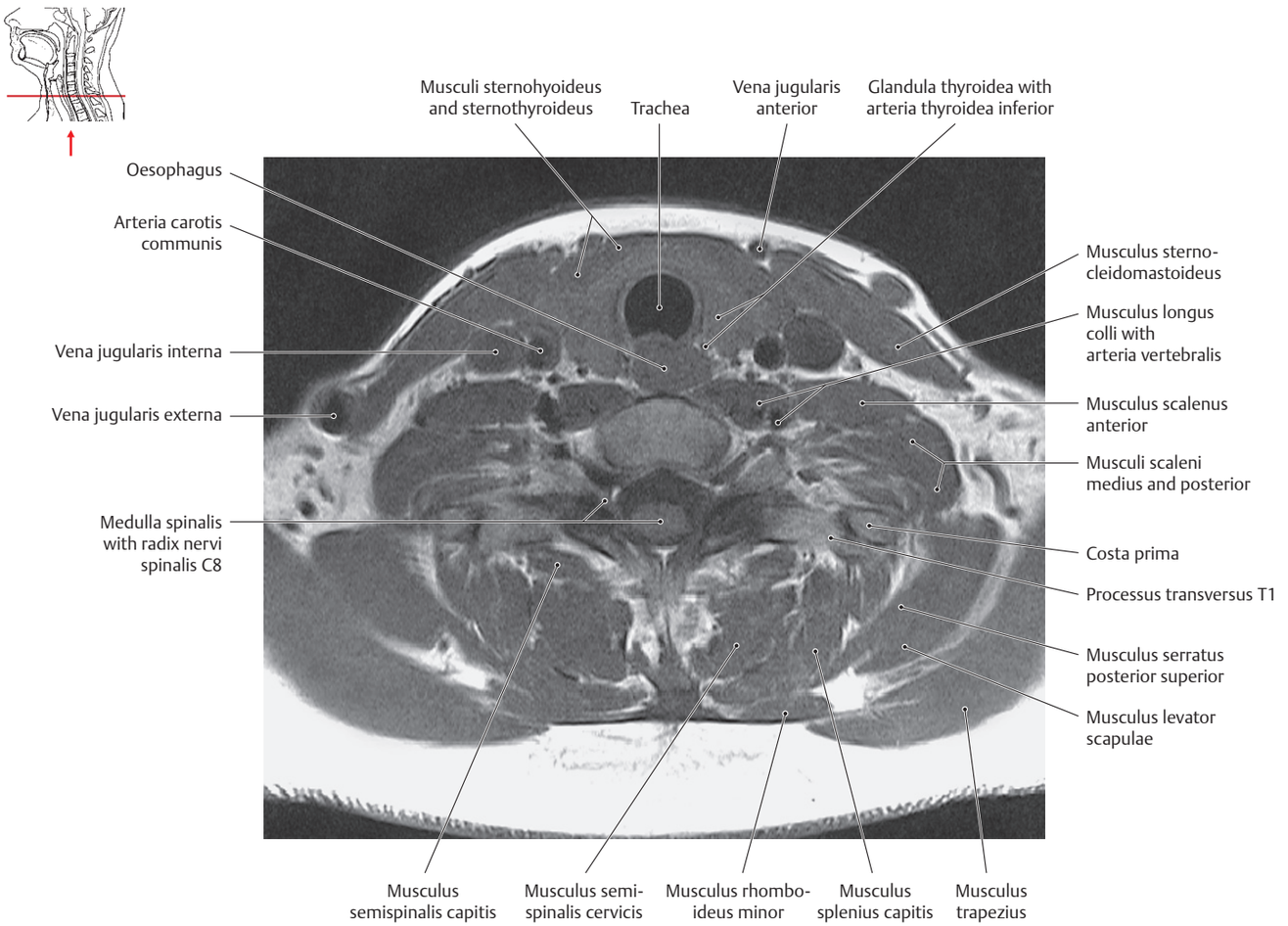


Fig. 14.32 **Transverse MRI through the vertebra C7**
Inferior view. This section demonstrates the relationship of the trachea to the oesophagus. Note the position of the vagina carotica (containing the arteria carotis communis, vena jugularis interna, and nervus vagus [CN X]) with respect to the glandula thyroidea. The radix nervi spinalis C8 can be seen emerging from the medulla spinalis. Note the costa prima and processus transversus of the thoracic vertebra.

Sagittal Sections of the Head (I): Medial

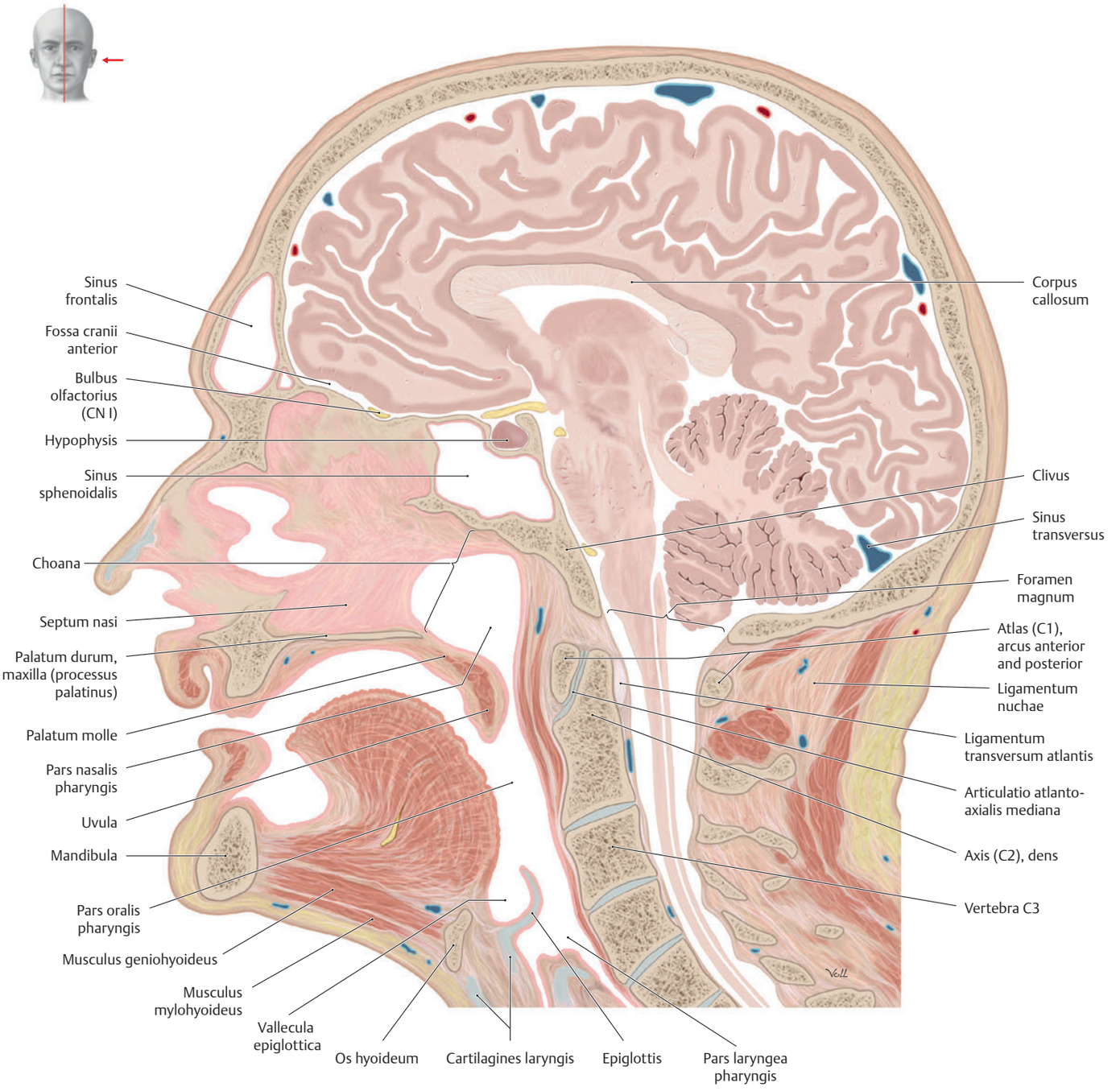


Fig. 14.33 **Midsagittal section through the septum nasi**
Left lateral view. The anatomical structures at this level can be roughly assigned to the facial skeleton or neurocranium (cranial vault). The lowest level of the facial skeleton is formed by the oral floor muscles between the os hyoideum and mandibula and the overlying skin. This section also passes through the epiglottis and the larynx below it, which are considered part of the cervical viscera. *Note:* The vallecula epiglottica, located in the pars oralis pharyngis, is bounded by the radix linguae and the epiglottis. The palata durum and molle with the uvula define the boundary between the cavitates oris and nasi. Posterior to the uvula is the pars oralis pharyngis. The section includes the septum nasi, which divides the cavitas nasi into two cavities (sectioned above and in front of the septum) that communicate with the pars nasalis pharyngis through the choanae. Posterior to the sinus frontalis is the fossa cranii anterior, which is part of the neurocranium. This section passes through the medial surface of the brain (the falx cerebri has been removed). The cut edge of the corpus callosum, the bulbus olfactorius, and the hypophysis are also shown.

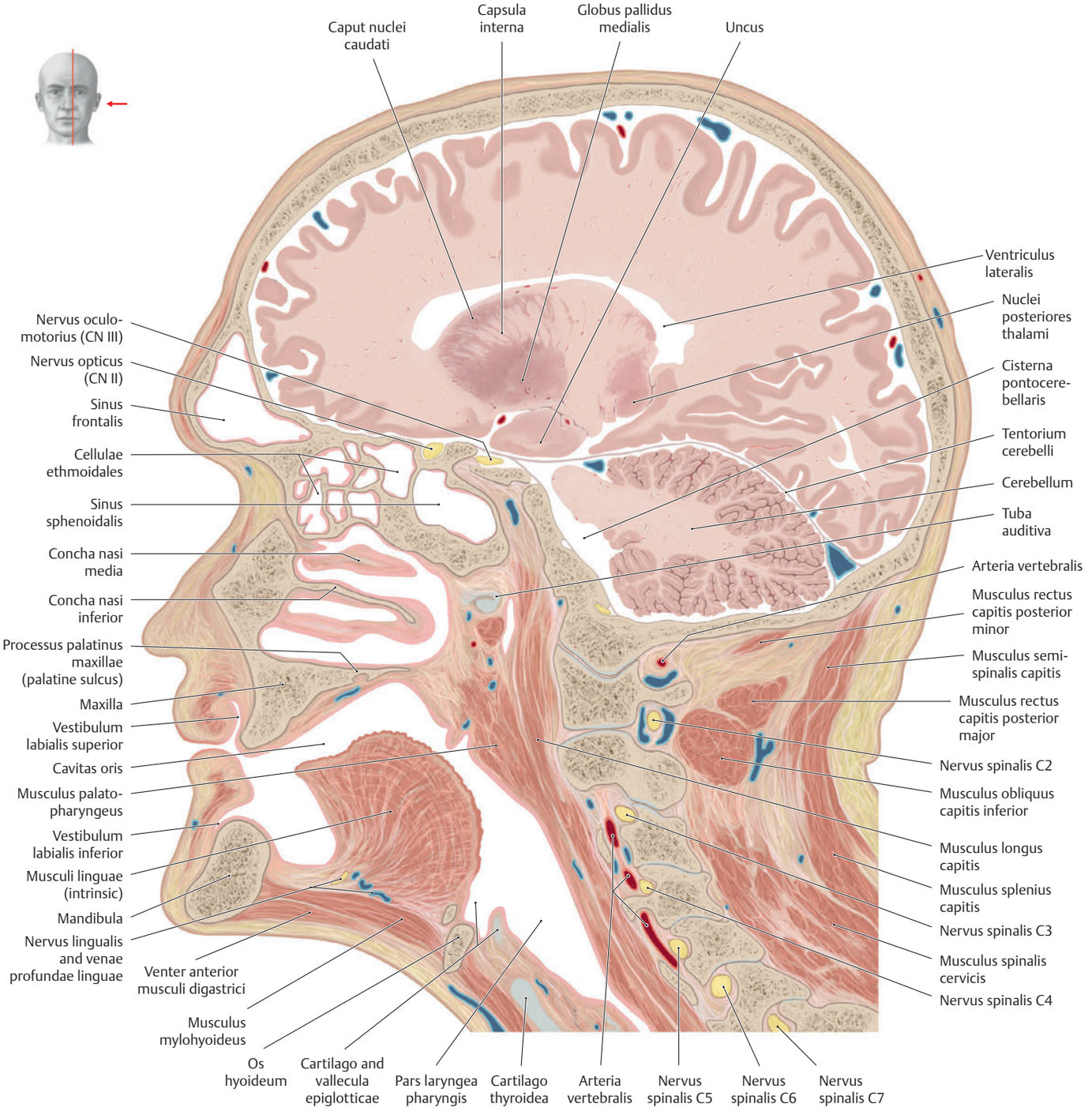


Fig. 14.34 **Sagittal section through the medial orbital wall**
Left lateral view. This section passes through the conchae nasi inferior and media within the cavitas nasi. Above the concha nasi media are the cellulae ethmoidales. The only parts of the pars nasalis pharyngis visible in this section are a small luminal area and the lateral wall, which bears a section of the pars cartilaginea of the tuba auditiva. The sinus sphenoidalis is also displayed. In the region of the cervical spine, the section cuts the arteria vertebralis at multiple levels. The lateral sites where the nervi spinales emerge from the foramina intervertebralia are clearly displayed. *Note:* This section is lateral to the musculus geniohyoideus.

Sagittal Sections of the Head (II): Lateral

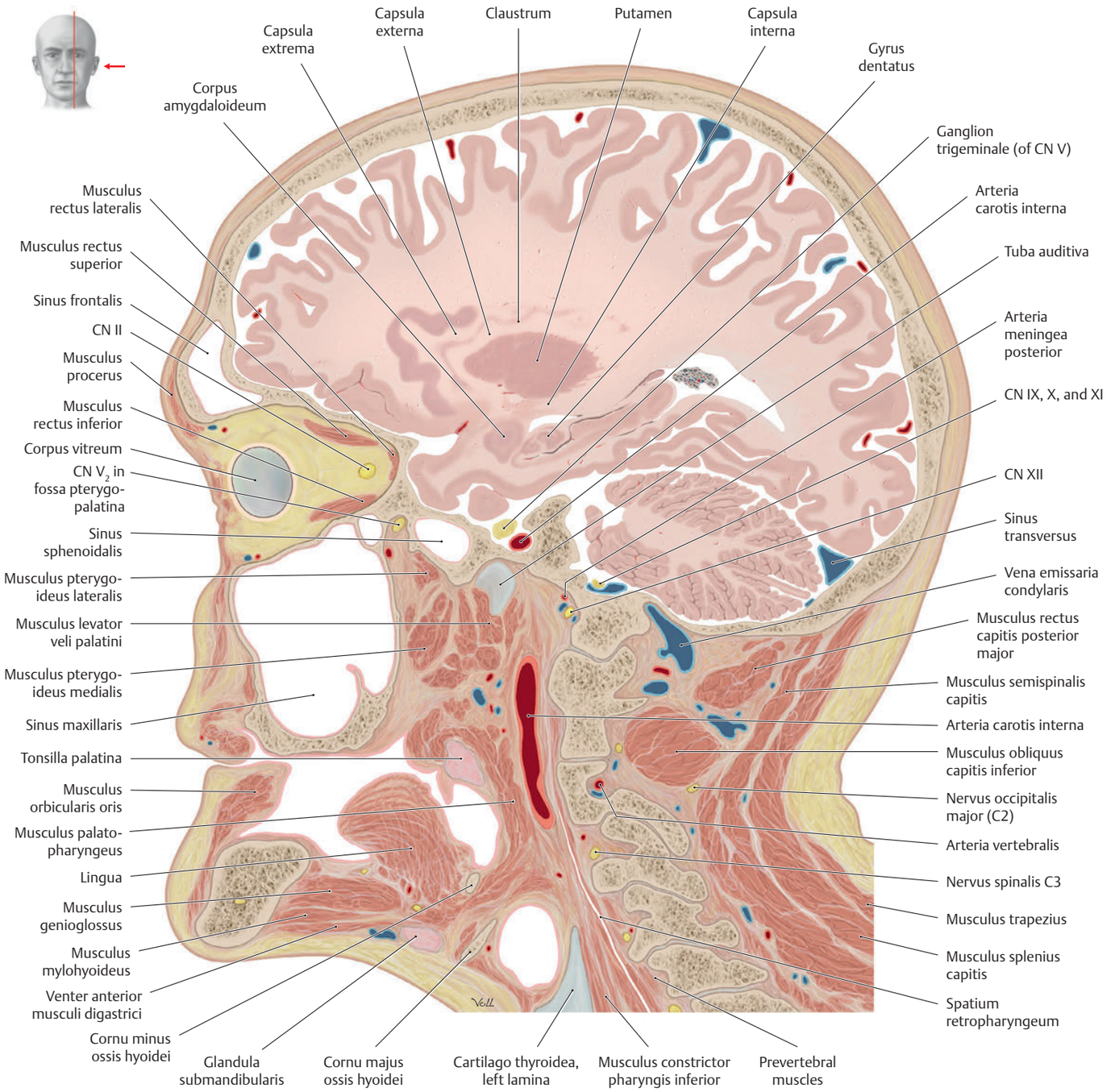


Fig. 14.35 **Sagittal section through the inner third of the orbita**
Left lateral view. This section passes through the sinus maxillaris and frontalis sinuses while displaying one cellula ethmoidalis and the peripheral part of the sinus sphenoidalis. It passes through the medial portion of the arteria carotis interna and glandula submandibularis. The musculi pharyngis and musculi masticatorii are grouped about the pars cartilaginea of the tuba auditiva. The bulbus oculi and nervus opticus are cut peripherally by the section, which displays relatively long segments of the musculi recti superior and inferior. Sectioned brain structures include the capsulae externa and interna and the intervening putamen. The corpus amygdaloideum can be identified near the base of the brain. A section of the ganglion trigeminale appears below the cerebrum.

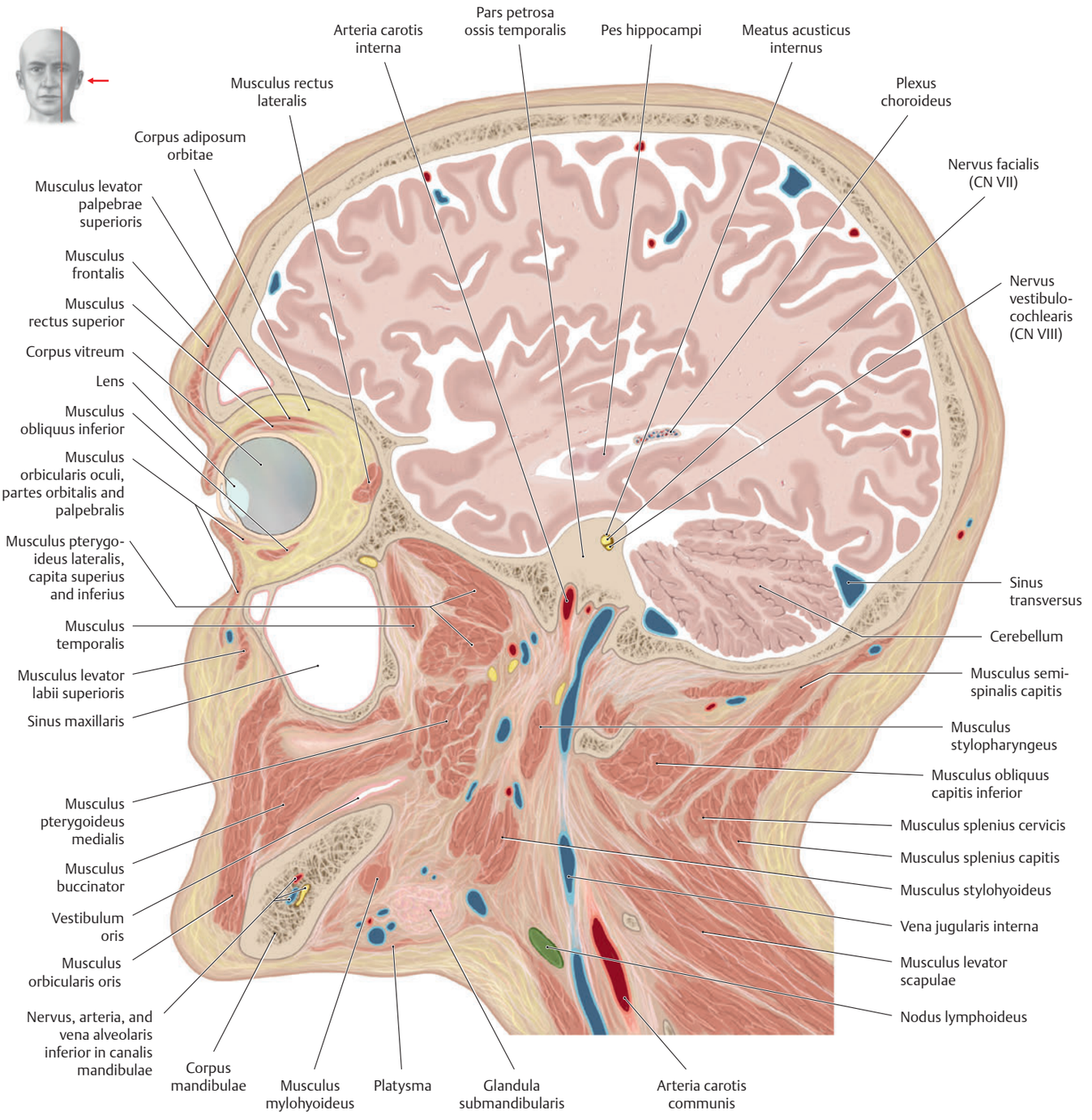
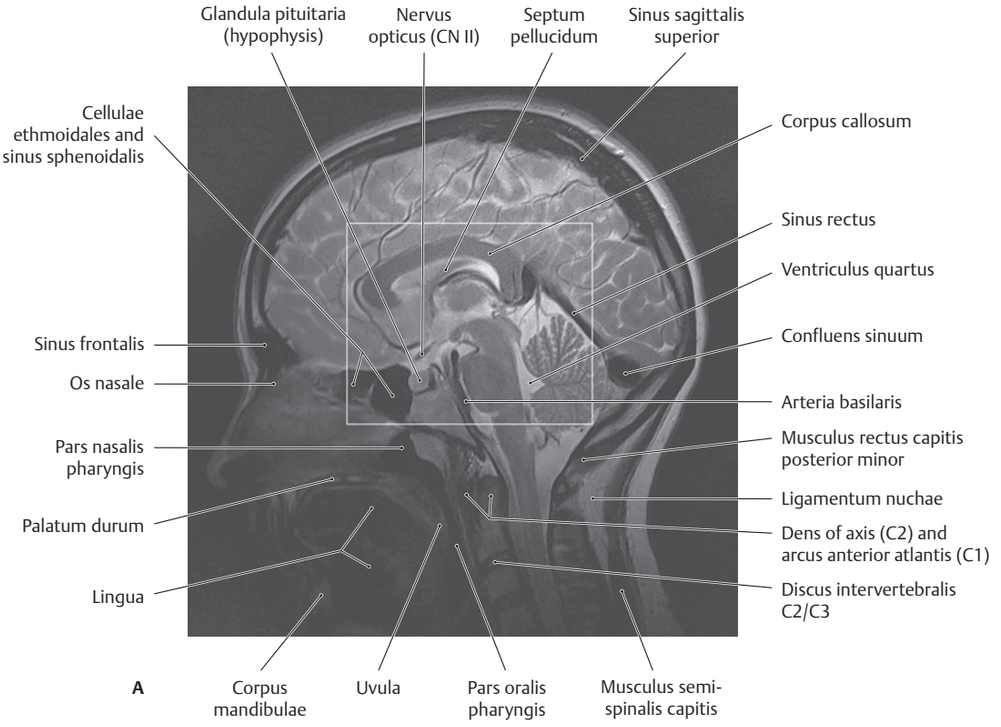


Fig. 14.36 **Sagittal section through the approximate center of the orbita**

Left lateral view. Due to the obliquity of this section, the dominant structure in the oral floor region is the mandibula, whereas the vestibulum oris appears as a narrow slit. The musculi buccales and masticatorii are prominently displayed. Much of the orbit is occupied by the bulbus oculi, which appears in longitudinal section. Aside from a few sections of the extraocular muscles, the orbit in this plane is filled with corpus adiposum orbitae. Both the arteria carotis interna and the vena jugularis interna are demonstrated. Except for the foot of the hippocampus, the only visible cerebral structures are the substantia alba and cortex. The nervus facialis and nervus vestibulocochlearis can be identified in the meatus acusticus internus.

Sagittal MRIs of the Head



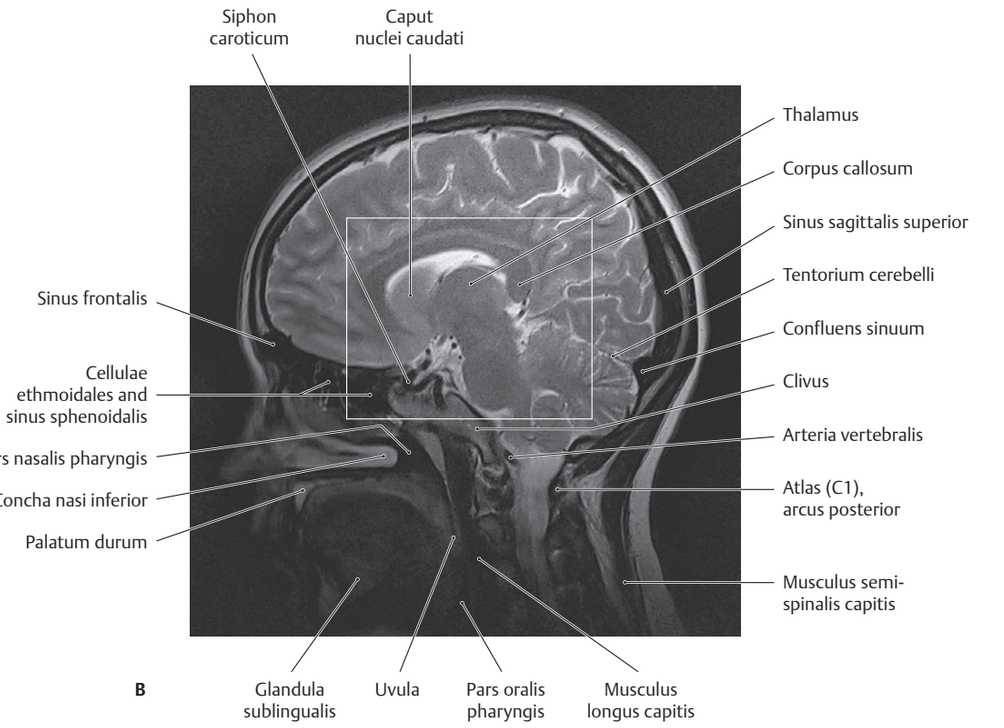


Fig. 14.37 **Sagittal sections through the cavitas nasi**
Left lateral view. **A** Midsagittal section through septum nasi. **B** Parasagittal section through conchae nasi inferior and media. These sections demonstrate the relationship of the pars nasalis pharyngis to the pars oralis pharyngis. The nervus opticus (CN II) is visible as the chiasma opticum in **A**. The glandula pituitaria (hypophysis) can be seen inferior to it, just posterior to the sinus sphenoidalis. The siphon caroticum is beautifully displayed in **B**.

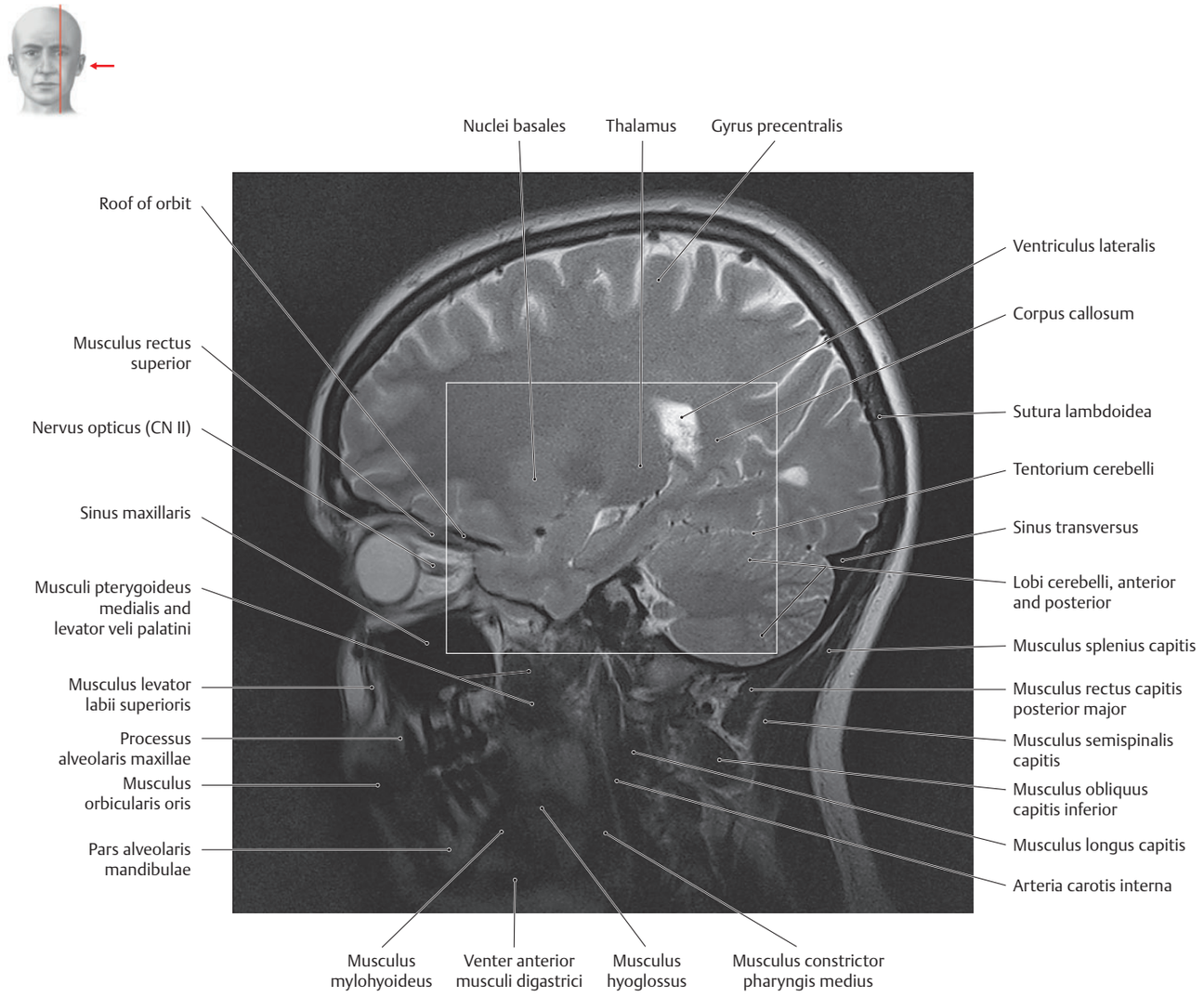


Fig. 14.38 **Parasagittal section through the orbita**
Left lateral view. This view exposes the superior and inferior within the corpus adiposus orbitae. The course of the nervus opticus (CN II) within the orbita can be seen. Note the proximity of the dentes maxillares to the sinus maxillaris. Roots of the dentes maxillares may erupt into the sinus maxillaris.

Sagittal MRIs of the Neck

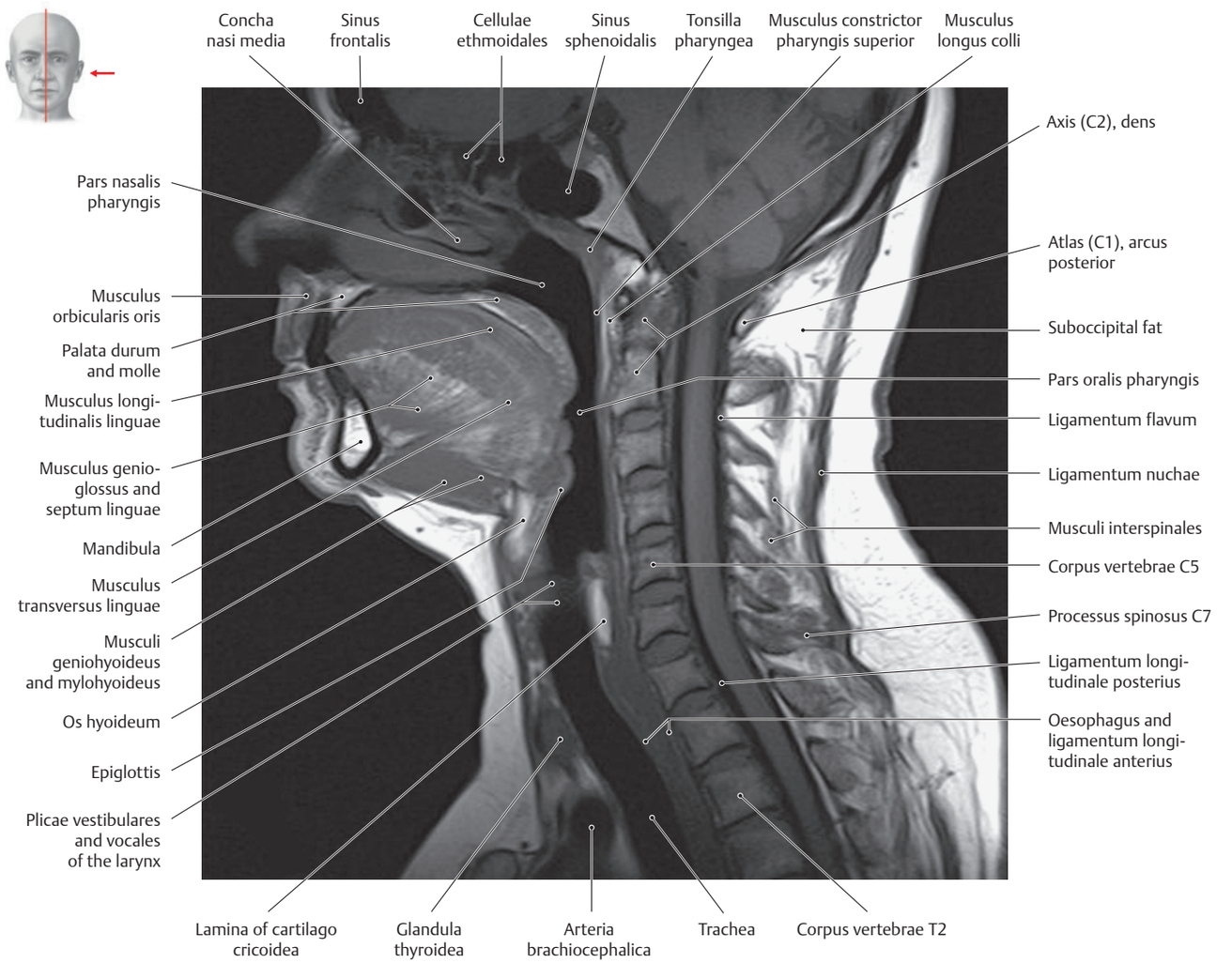


Fig. 14.39 **Midsagittal section**
Left lateral view. This section illustrates the relations between the cavitas nasi and cellulae ethmoidales. The cavitas nasi communicates posteriorly (via the choanae) with the pars nasalis pharyngis, which is separated from the cavitas oris by the palatum molle and uvula. Inferior to the uvula, the pars nasalis pharyngis and cavitas oris converge in the pars oralis pharyngis. Air continues more anteriorly into the pars laryngea pharyngis and ultimately the trachea, whereas food passes into the oesophagus, posterior to the lamina of the larynx. Note how closely opposed the oesophagus is to the anterior surface of the corpora vertebralia. This section also reveals the cervical vertebrae and ligaments.

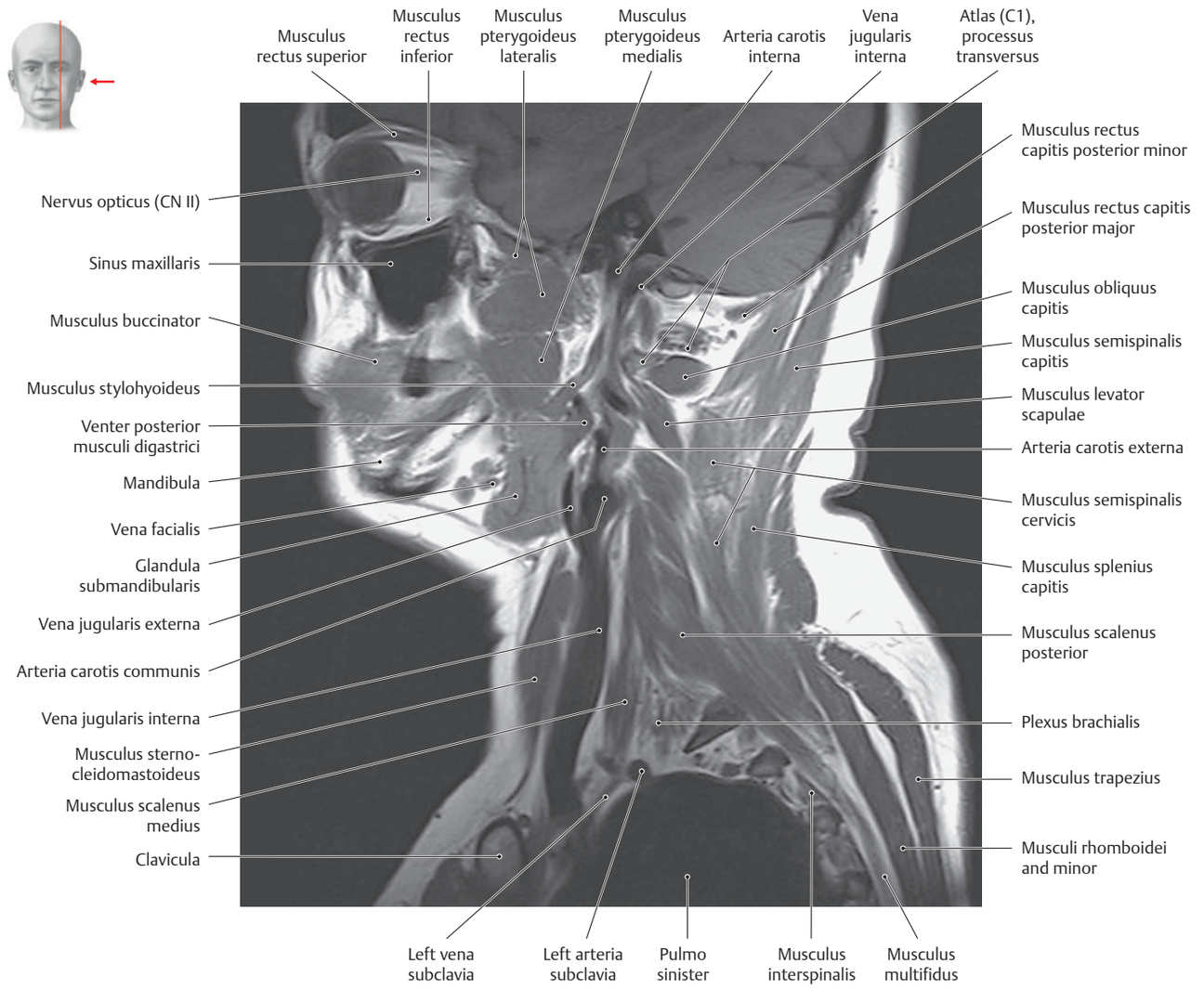
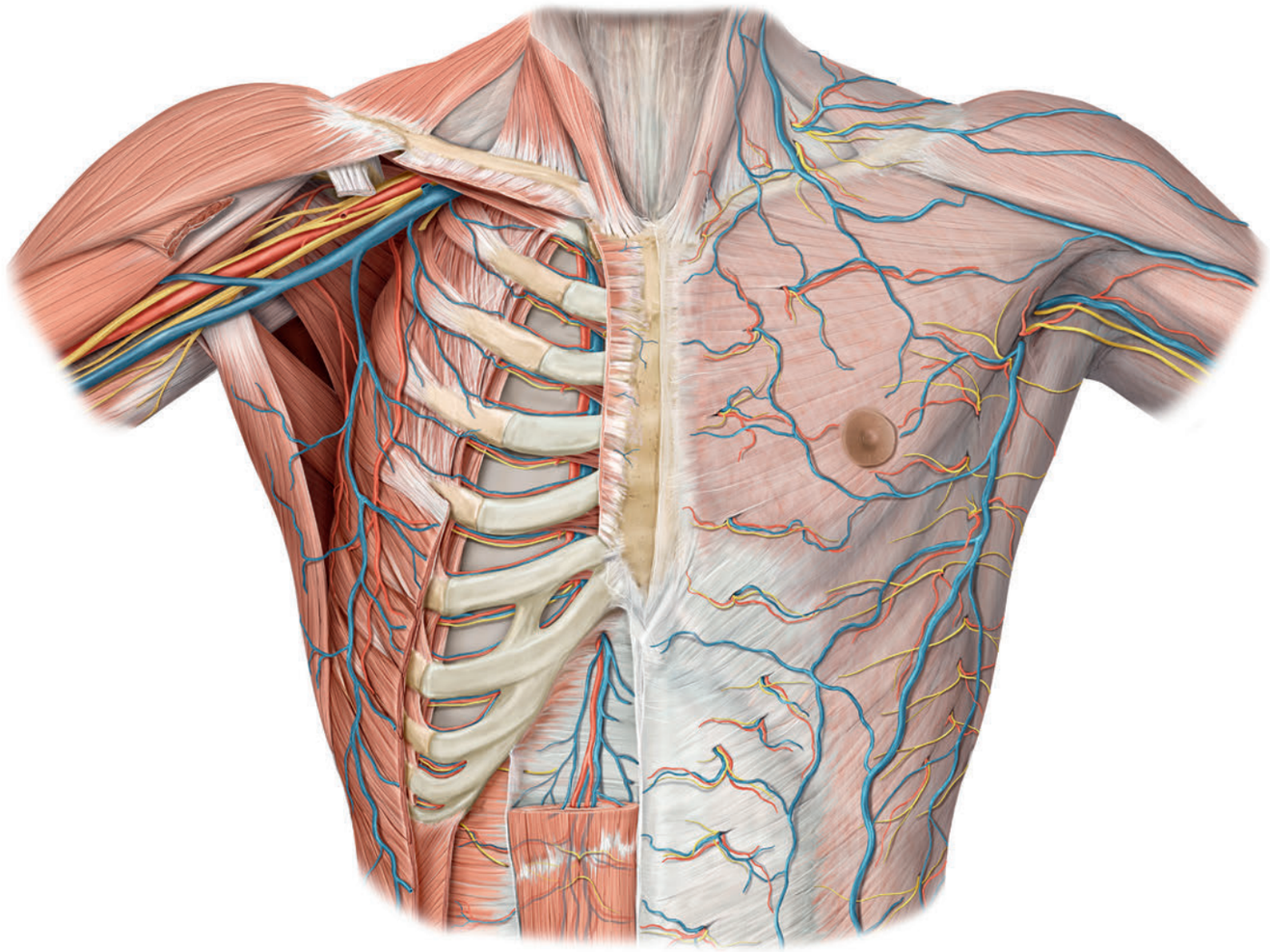


Fig. 14.40 **Sagittal section through bifurcatio carotidis**
Left lateral view. This section shows the arteriae carotides communis and externa, as well as the venae jugulares interna and externa. The craniovertebral joint muscles are visible along with the nuchal muscles. Note the position of the plexus brachialis between the musculi scaleni medius and posterior. The extent of the glandula submandibularis can be appreciated in this view.



Rest of Body Anatomy

15 Rest of Body Anatomy

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Clavicula & Scapula

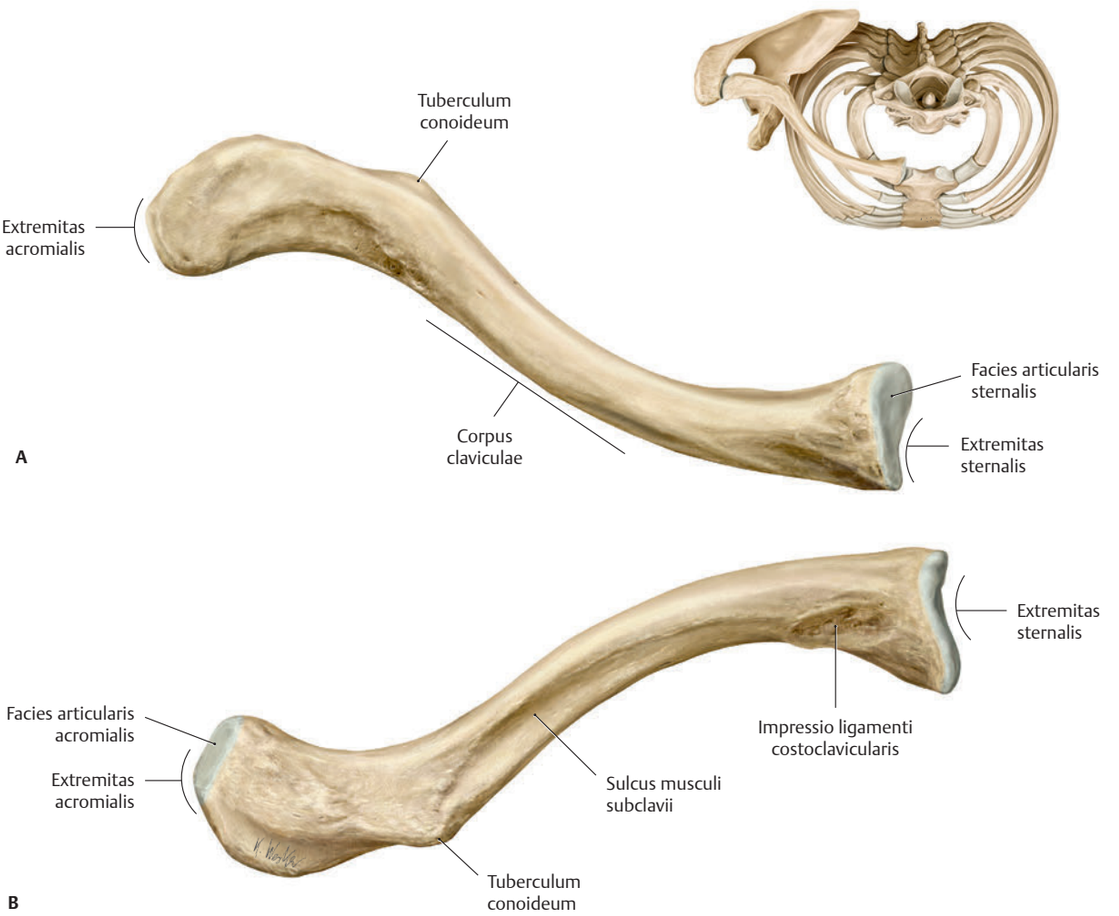
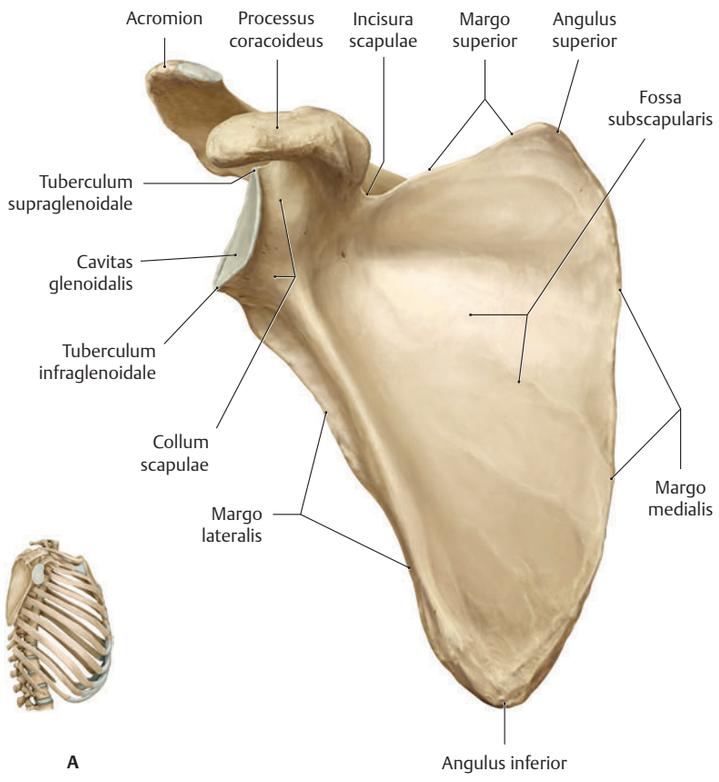
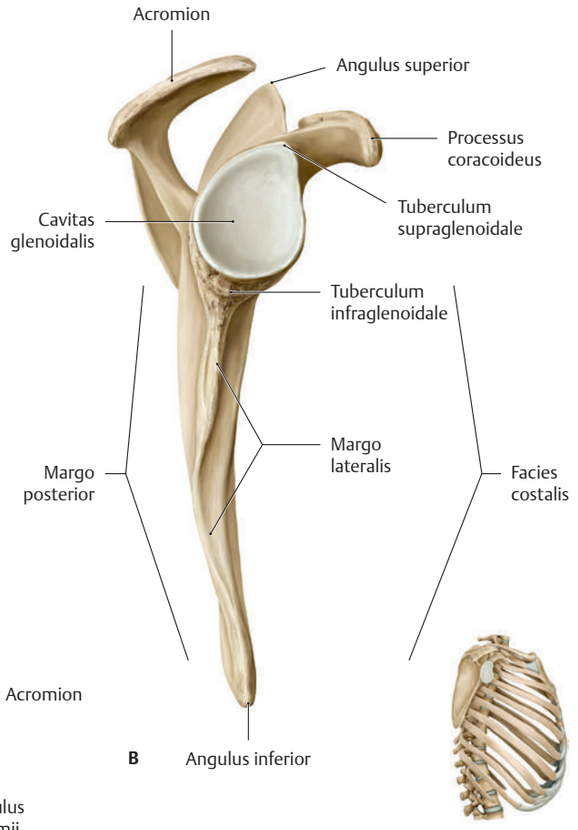


Fig. 15.1 **Clavicula**
Right clavicula. **A** Superior view; **B** inferior view. The S-shaped clavicula is visible and palpable along its entire length. Its medial end articulates with the sternum at the articulatio sternoclavicularis. Its lateral end articulates with the scapula at the articulatio acromioclavicularis. The clavicula and scapula connect the bones of the upper limb to the cavea thoracis.





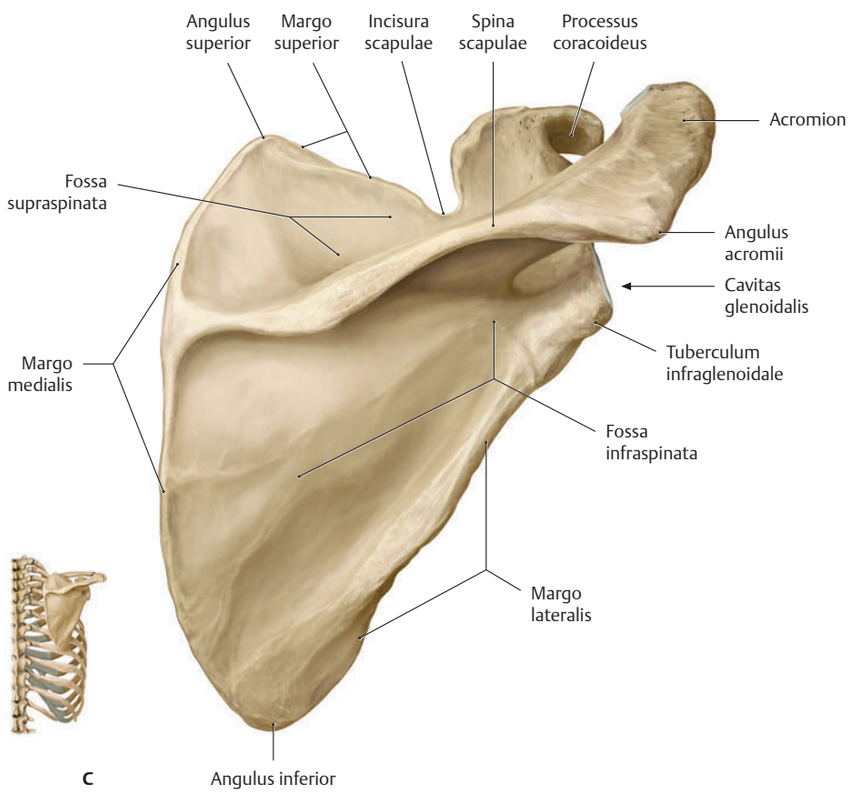


Fig. 15.2 **Scapula**
Right scapula. **A** Anterior view; **B** right lateral view; **C** posterior view. In its normal anatomic position, the scapula extends from the 2nd to the 7th rib.

Humerus & Articulatio Glenohumeralis

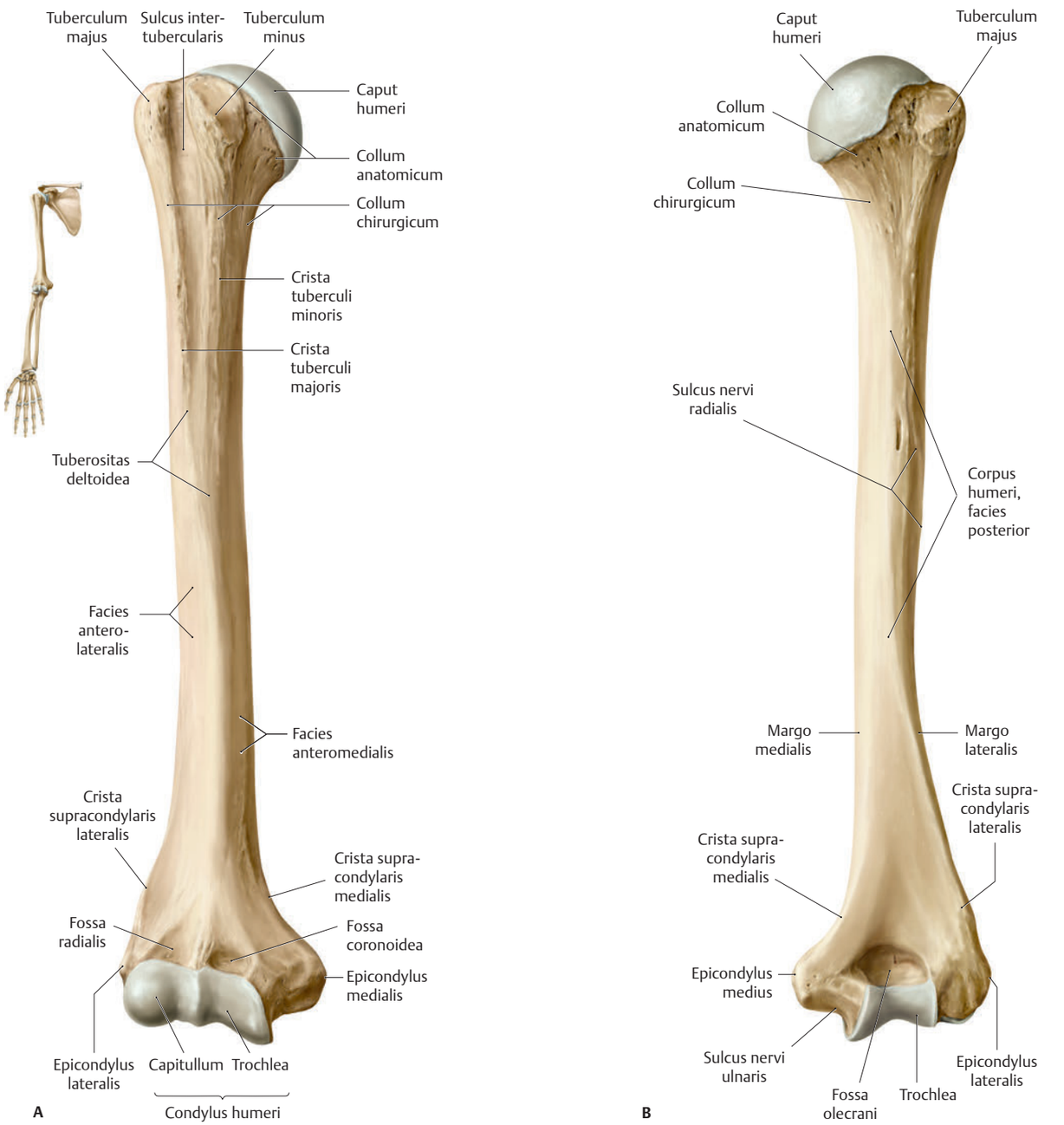


Fig. 15.3 **Humerus**
Right humerus. **A** Anterior view. **B** Posterior view.
The caput humeri articulates with the scapula at the articulatio glenohumeralis. The capitullum and trochlea of the humerus articulate with the radius and ulna, respectively, at the articulatio cubiti.

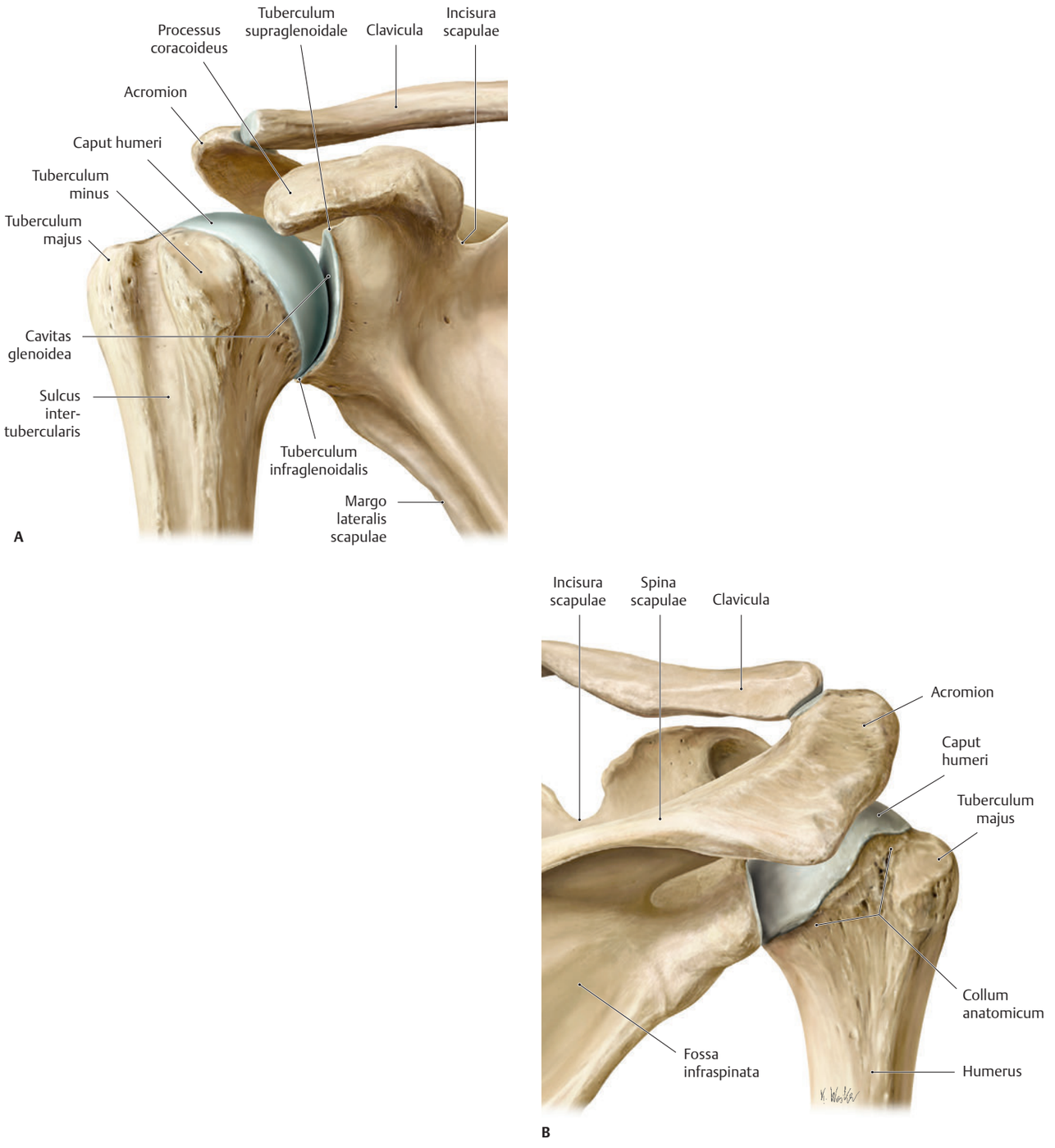


Fig. 15.4 **Articulatio glenohumeralis: Bony elements**
Right shoulder. **A** Anterior view. **B** Posterior view.

Bones of Forearm, Wrist, & Hand

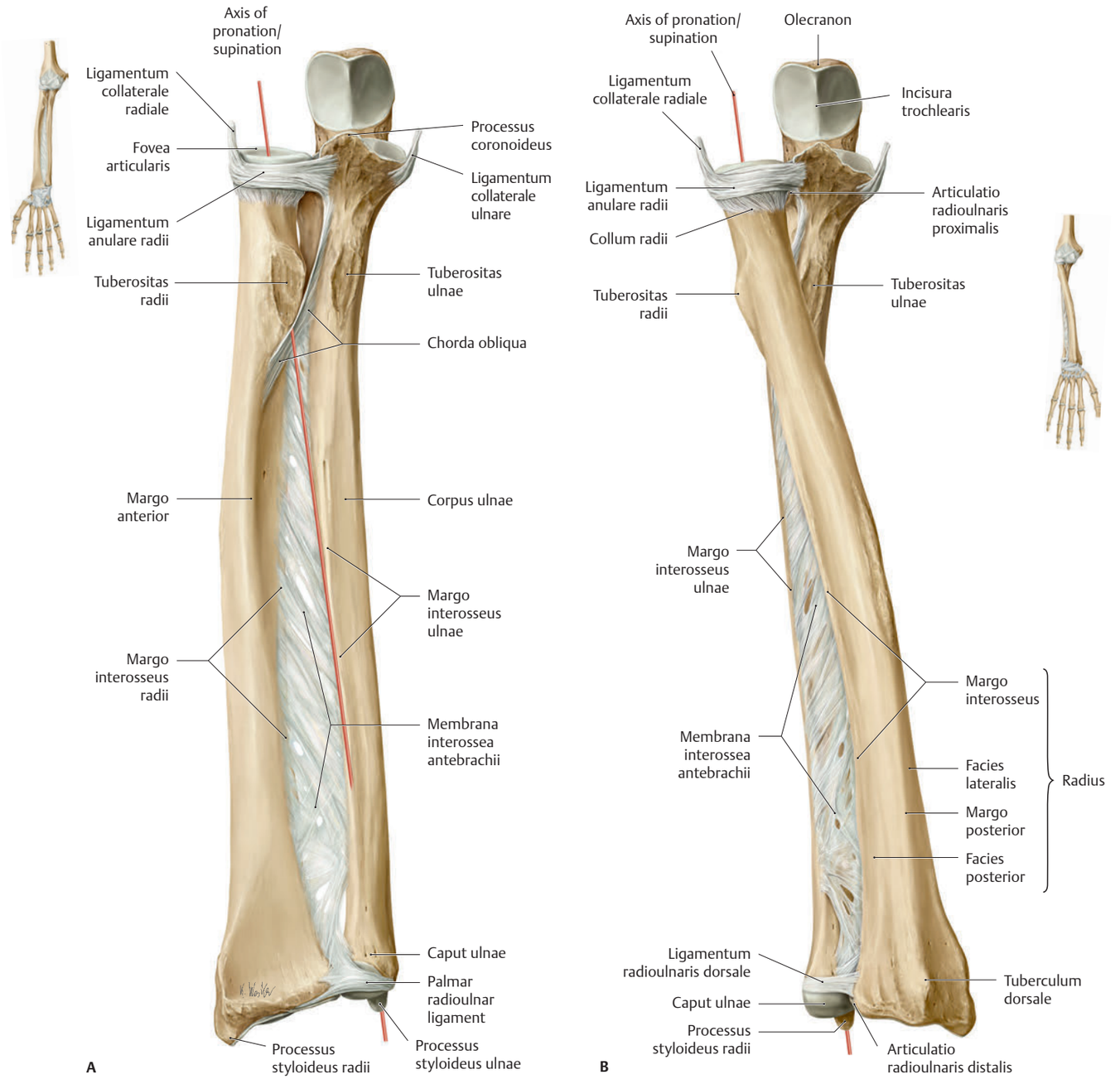


Fig. 15.5 **Radius and Ulna**
Right forearm, anterior view. **A** Supination. **B** Pronation.

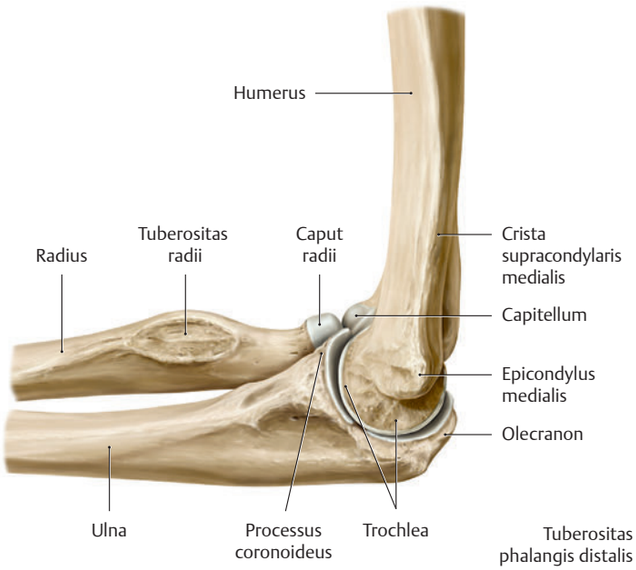


Fig. 15.6 **Articulatio cubiti**
Right limb. The cubitus consists of three articulations between the humerus, ulna, and radius: the articulationes humeroulnaris, humeroradialis, and radioulnaris proximalis.

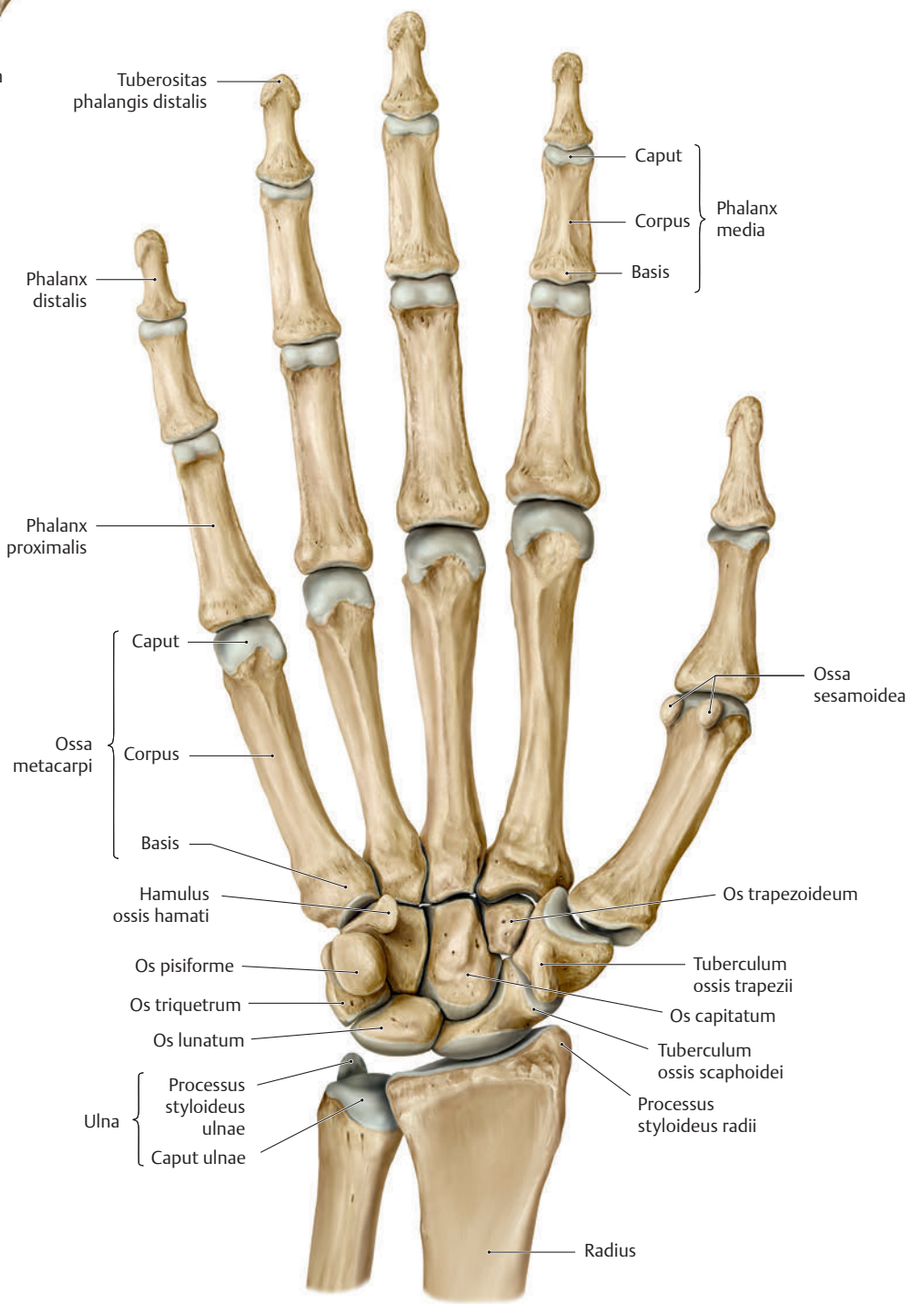


Fig. 15.7 **Hand**
Right hand, palmar view.

Muscles of the Shoulder (I)

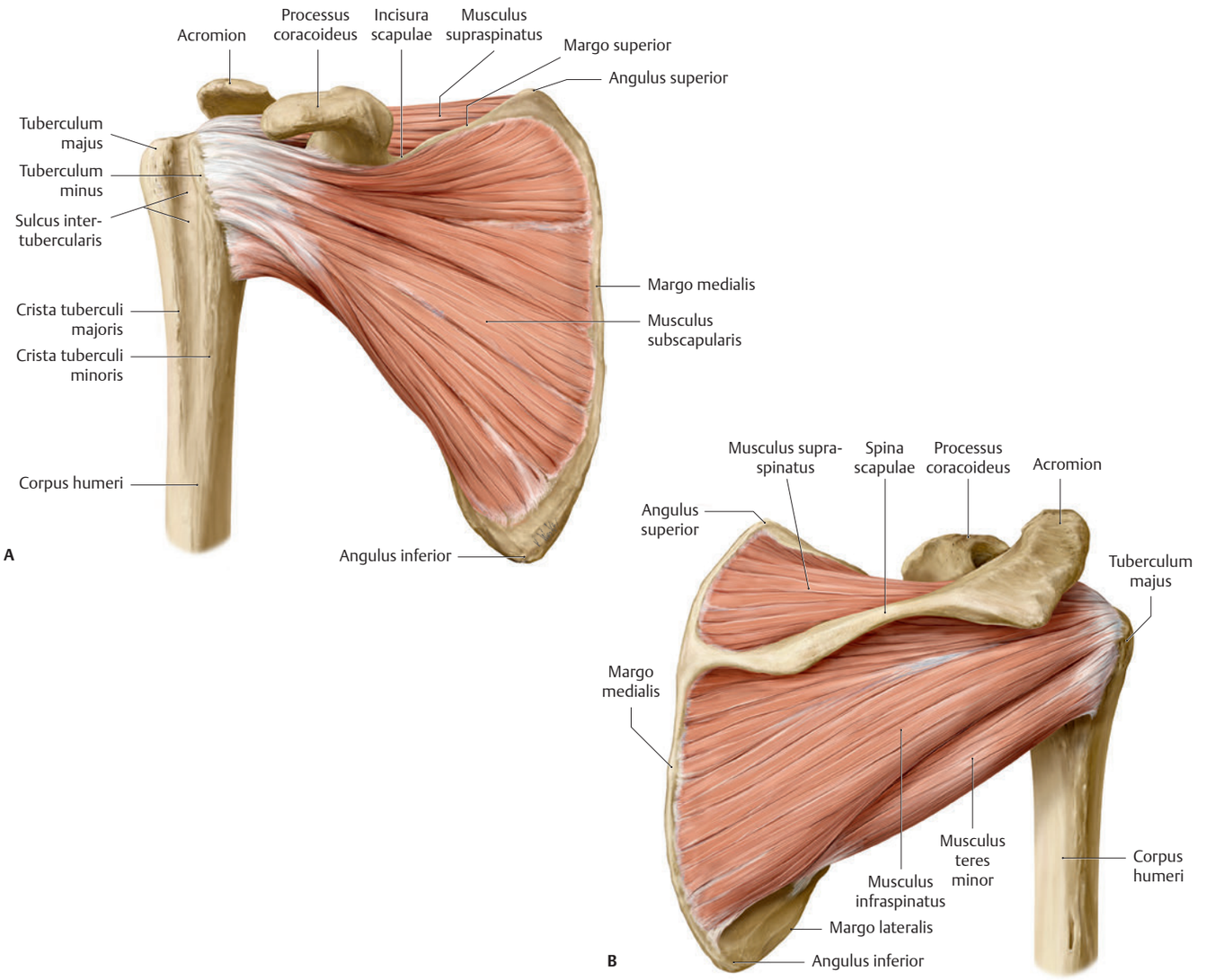


Fig. 15.8 **Serratus anterior**
Right shoulder. **A** Anterior view. **B** Posterior view.
The rotator cuff consists of four muscles: musculi supraspinatus, infraspinatus, teres minor, and subscapularis.

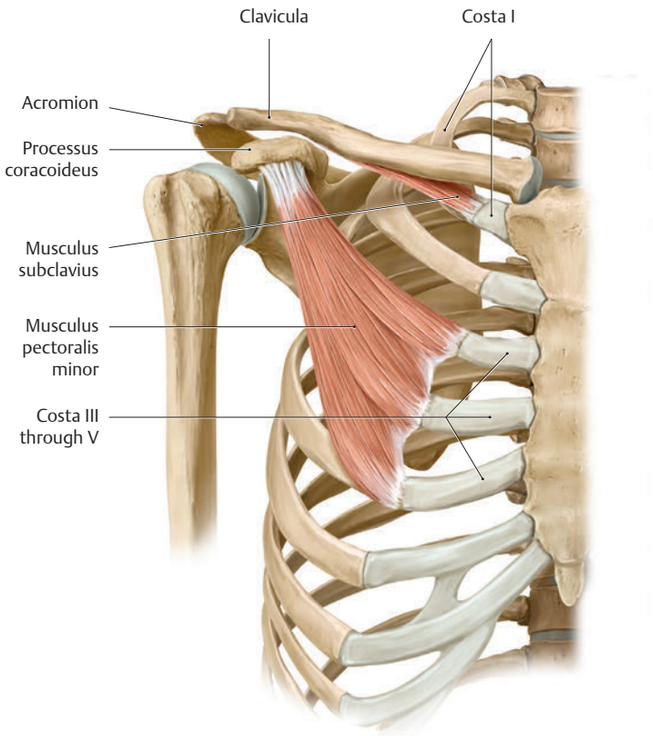


Fig. 15.9 **Musculi subclavius and pectoralis minor**
Right side, anterior view.

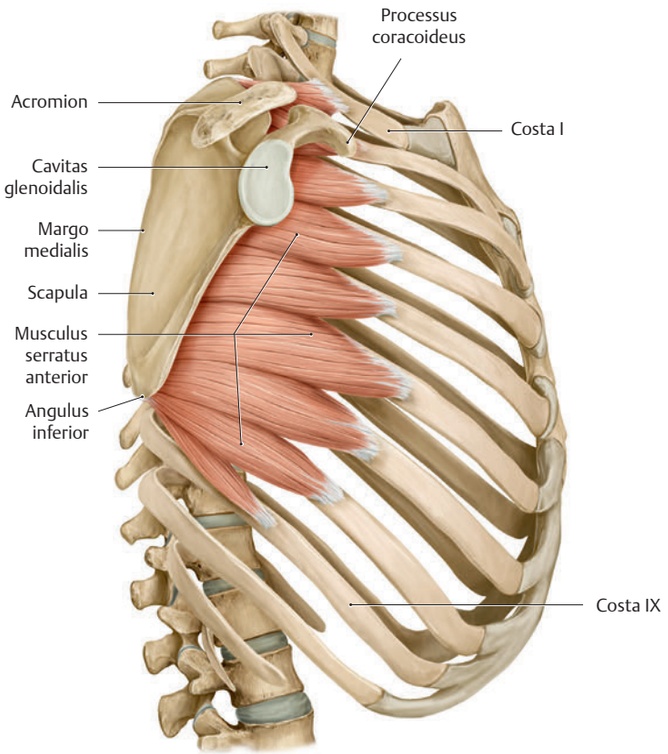


Fig. 15.10 **Musculus serratus anterior**
Right lateral view.

Muscles of the Shoulder (II) & Arm

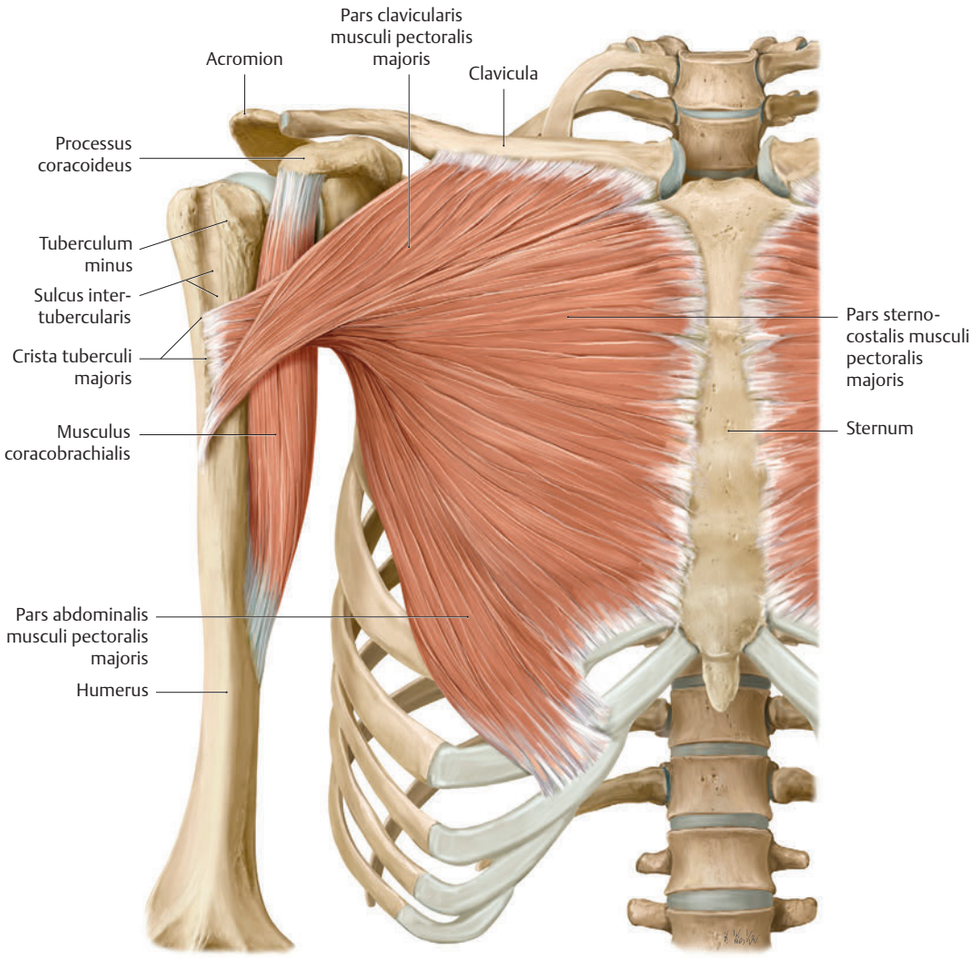


Fig. 15.11 **Musculi pectoralis major and coracobrachialis**
Anterior view.

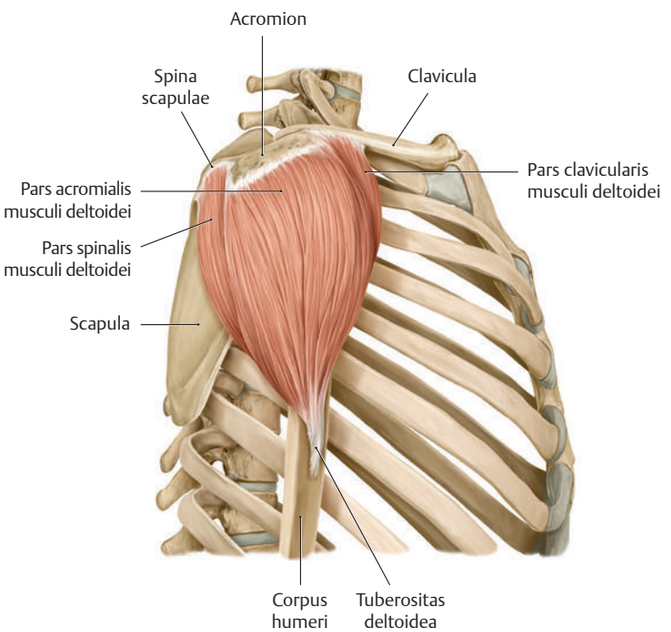


Fig. 15.12 **Musculus deltoideus**
Right shoulder, right lateral view.

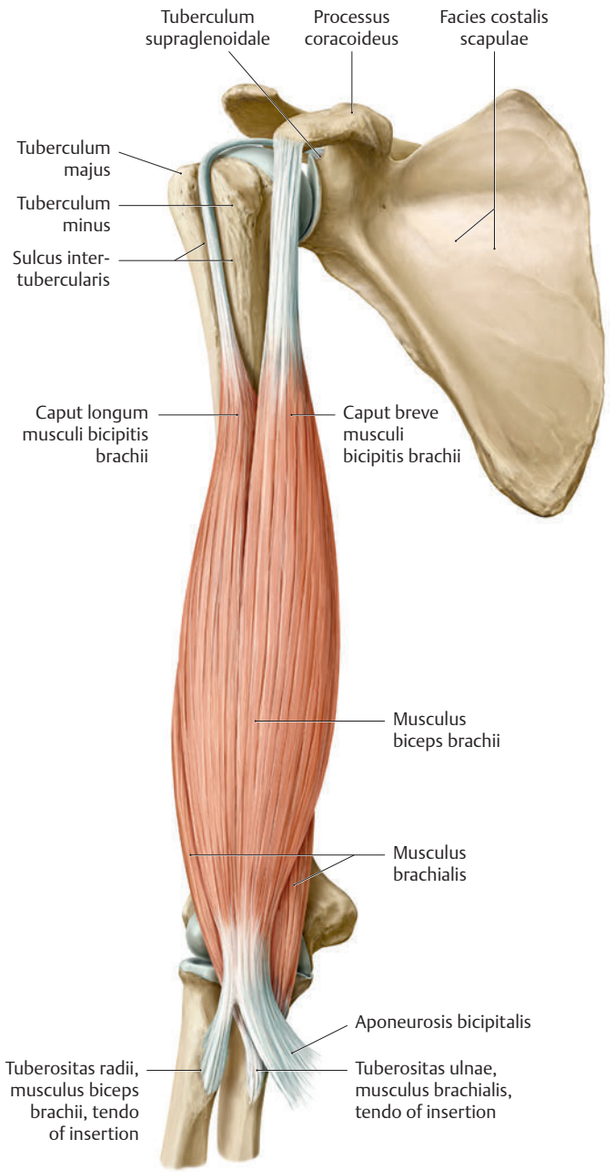


Fig. 15.13 **Right shoulder, right lateral view.**
Right arm, anterior view.

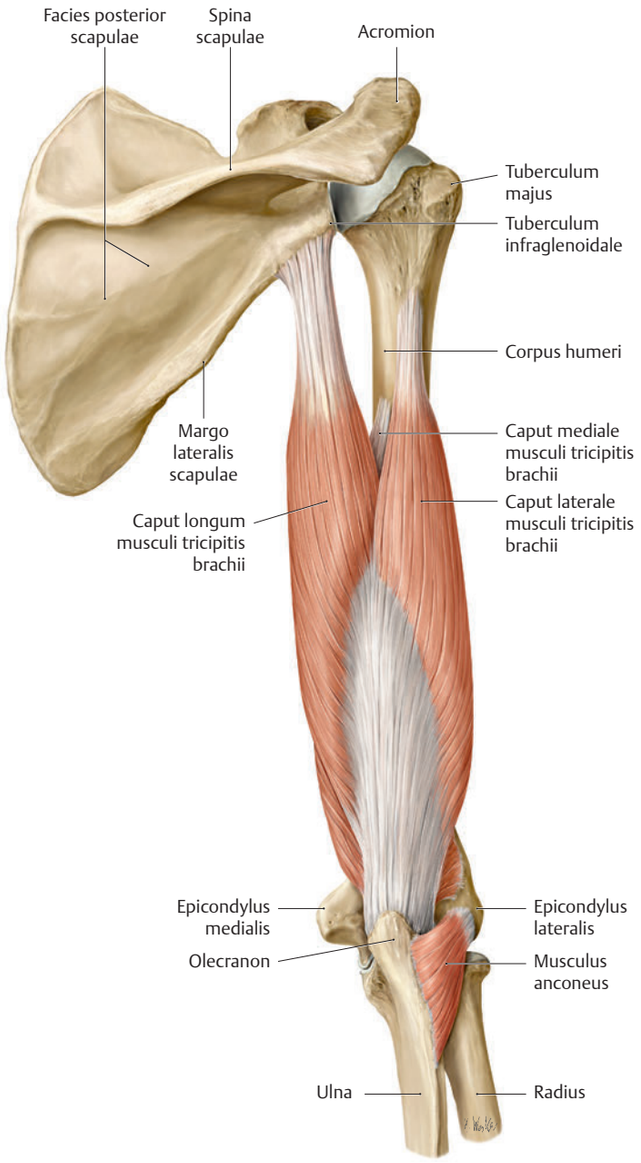


Fig. 15.14 **Musculi triceps brachii and anconeus**
Right arm, posterior view.

Muscles of the Forearm

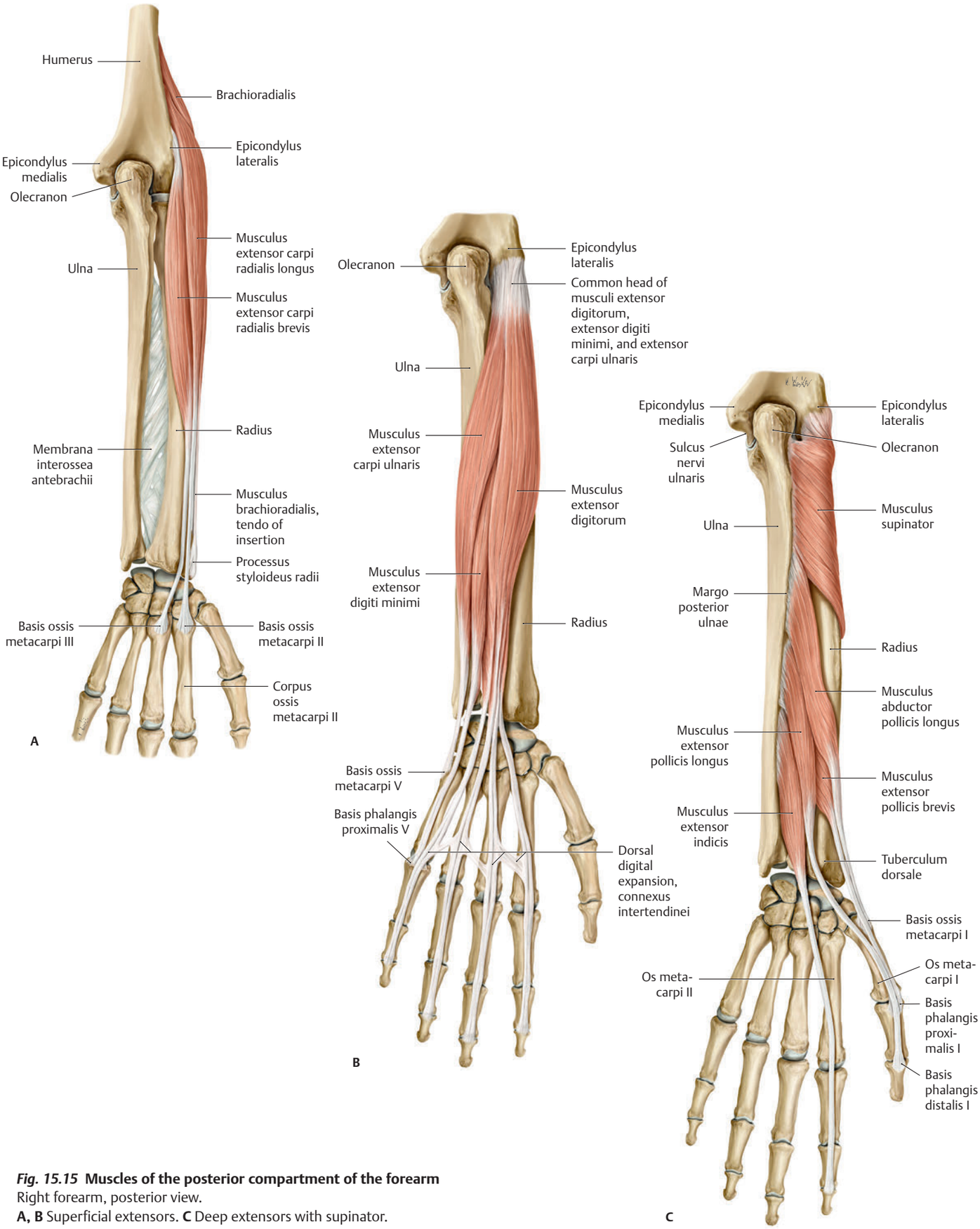


Fig. 15.15 **Muscles of the posterior compartment of the forearm**
Right forearm, posterior view.
A, B Superficial extensors. **C** Deep extensors with supinator.

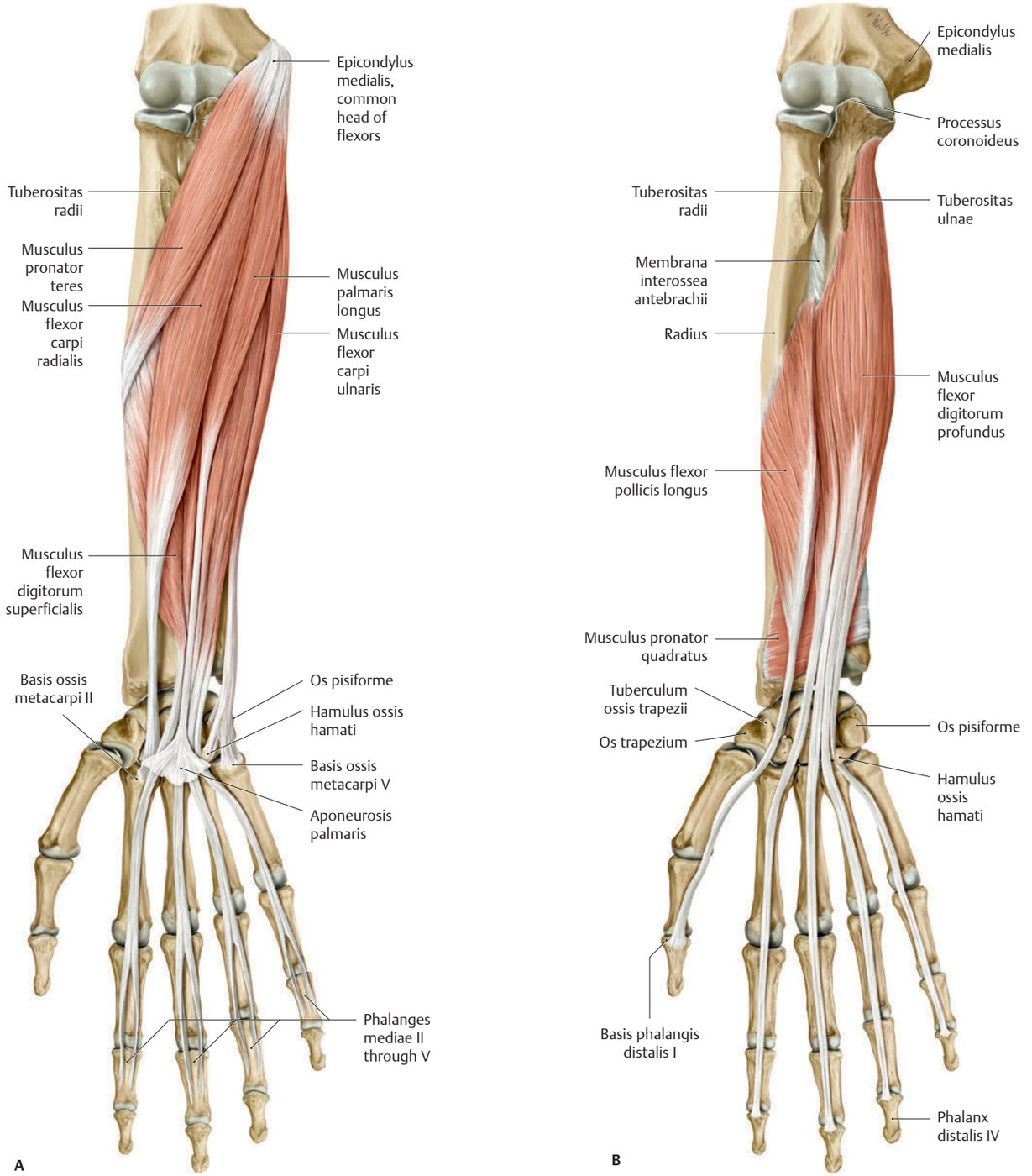


Fig. 15.16 **Muscles of the anterior compartment of the forearm**
Right forearm, anterior view.

A Superficial and intermediate muscles.
B Deep muscles.

Muscles of the Wrist & Hand

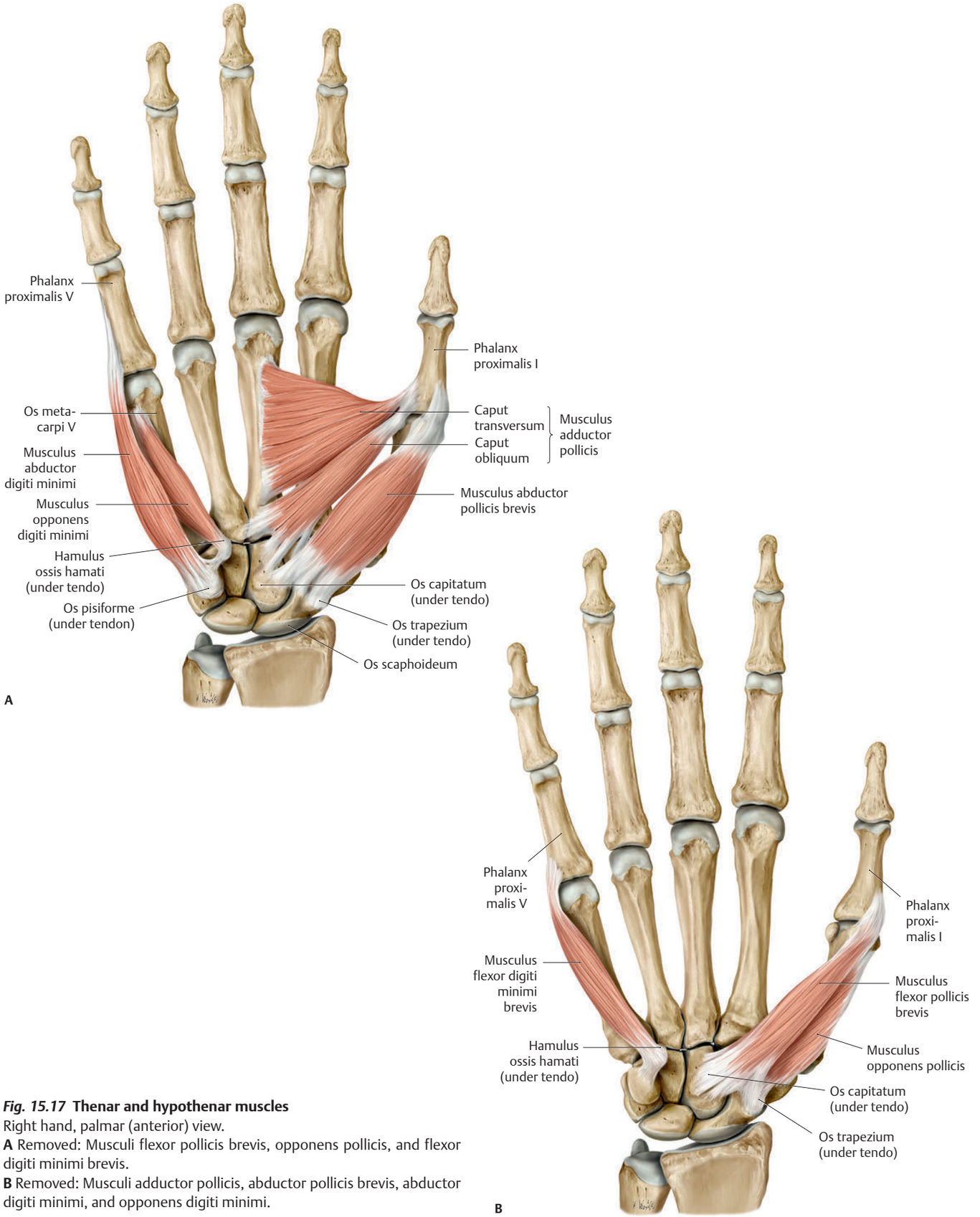


Fig. 15.17 **Thenar and hypothenar muscles**
Right hand, palmar (anterior) view.
A Removed: Musculi flexor pollicis brevis, opponens pollicis, and flexor digiti minimi brevis.
B Removed: Musculi adductor pollicis, abductor pollicis brevis, abductor digiti minimi, and opponens digiti minimi.

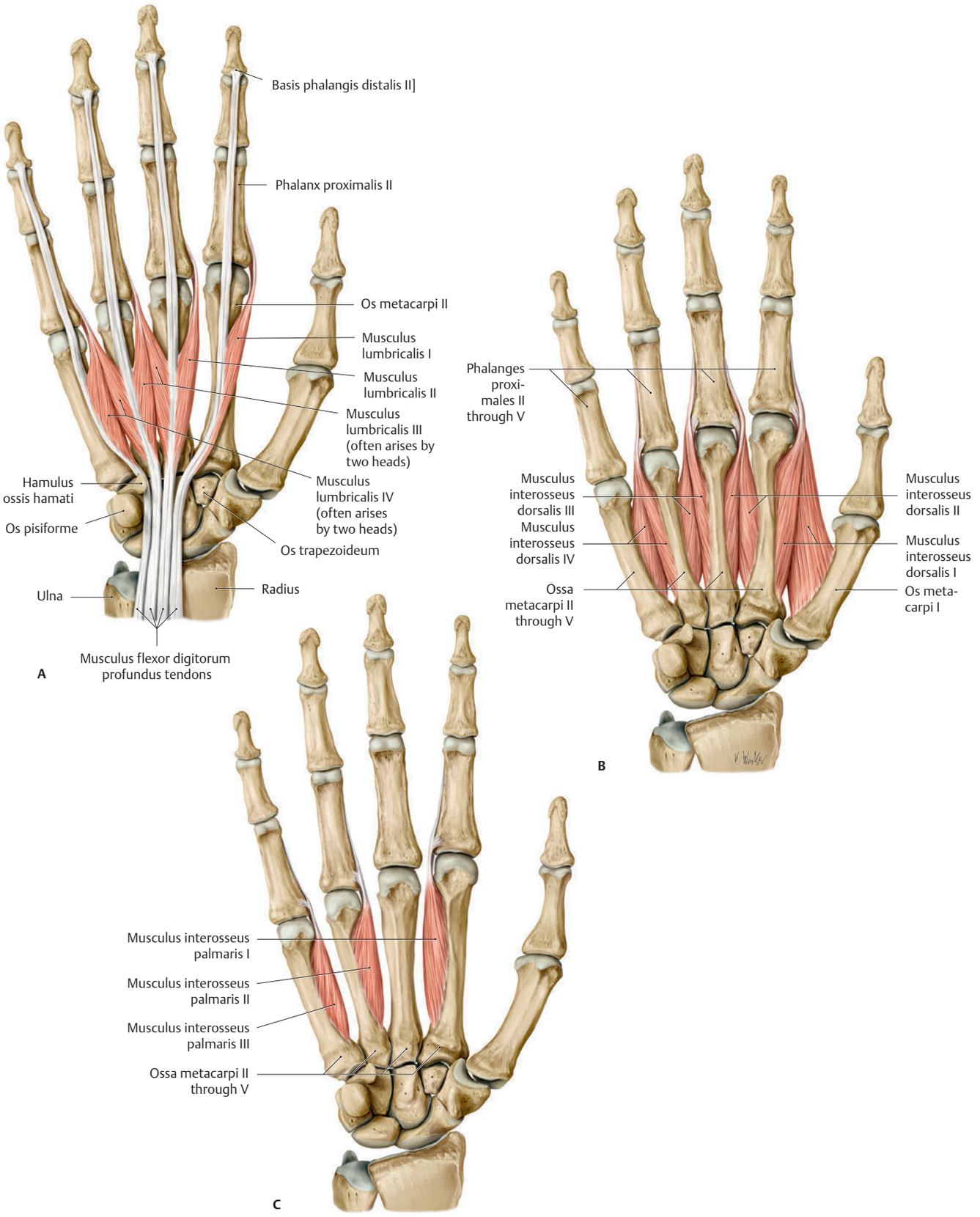


Fig. 15.18 **Metacarpal muscles**
Right hand, palmar (anterior) view.
A Musculi lumbricales.
B Musculi interossei dorsales.
C Musculi interossei palmares.

Arteries & Veins of the Upper Limb

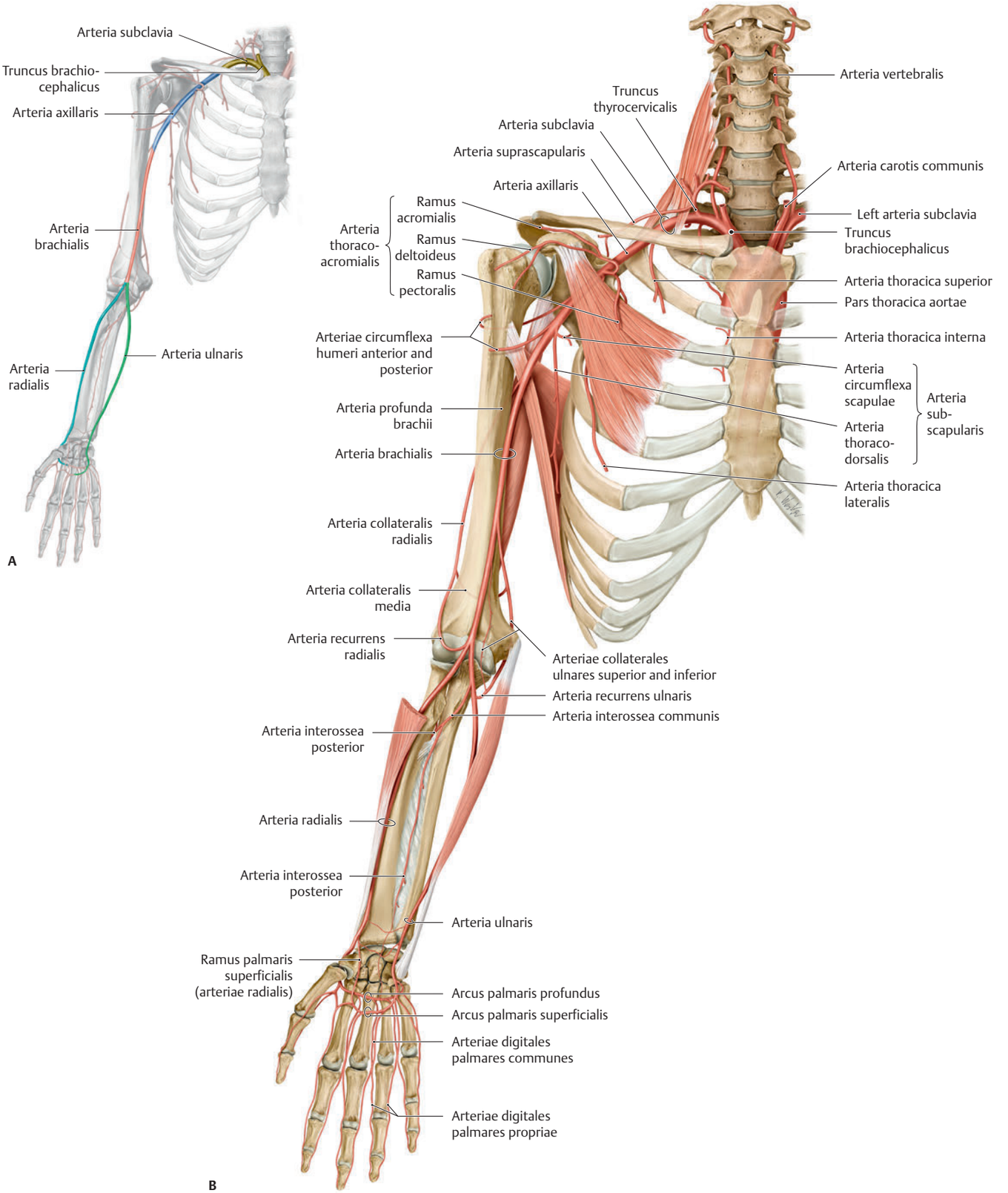


Fig. 15.19 **Arteries of the upper limb**
Right limb, anterior view.
A Main arterial segments.
B Course of the arteries.

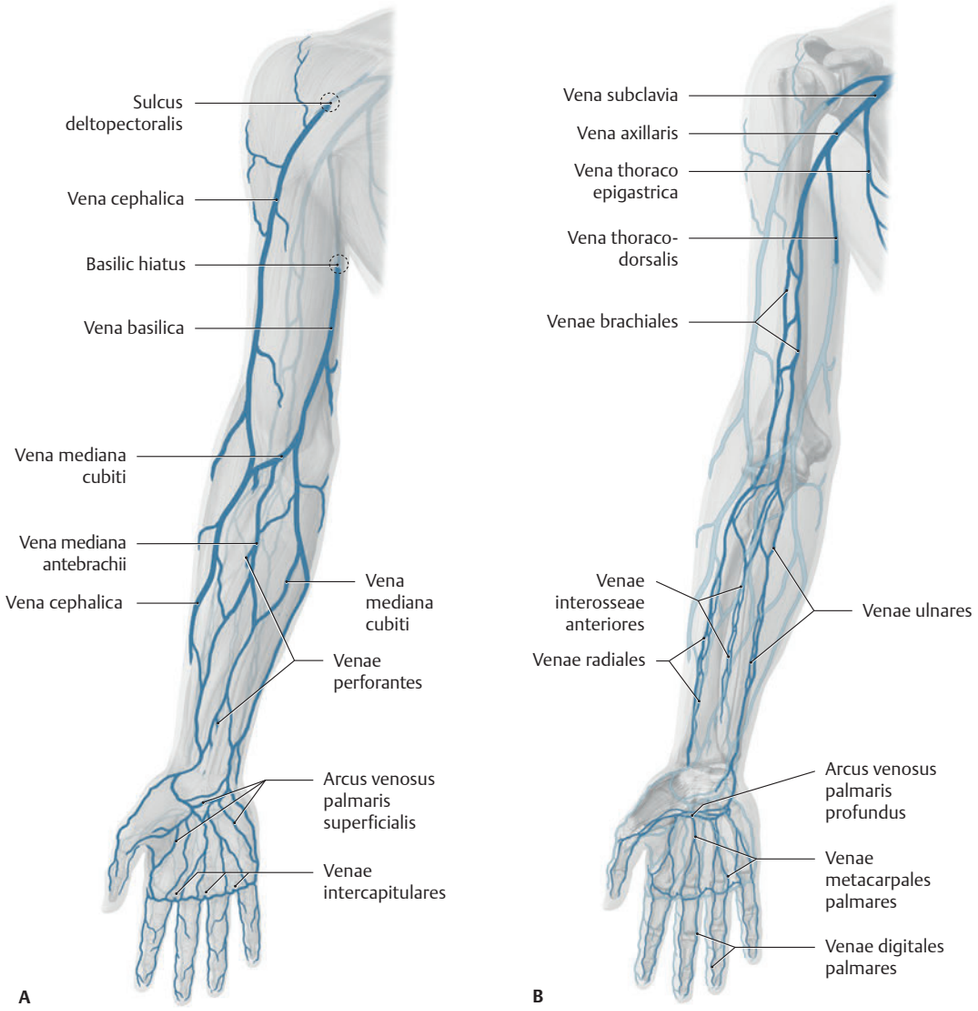


Fig. 15.20 **Veins of the upper limb**
Right limb, anterior view.
A Superficial veins.
B Deep veins.

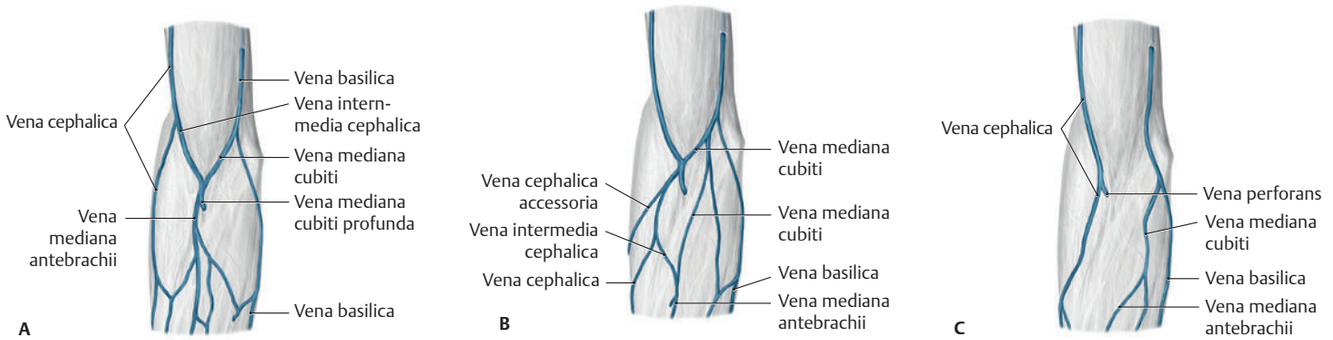


Fig. 15.21 **Veins of the fossa cubitalis**
Right limb, anterior view. The subcutaneous veins of the fossa cubitalis have a highly variable course.
A M-shaped.
B With vena cephalica accessoria.
C Without vena mediana cubiti.

Plexus Brachialis

Almost all muscles in the upper limb are innervated by the plexus brachialis, which arises from segments C5 to T1 of medulla spinalis. The rami anteriores of the nervi spinales give off direct branches (pars supraclavicularis of the plexus brachialis) and merge to form three trunci, six divisiones (three anterior and three posterior), and three fasciculi. The pars infraclavicularis of the plexus brachialis consists of short branches that arise directly from the fasciculi and long (terminal) branches that traverse the limb.

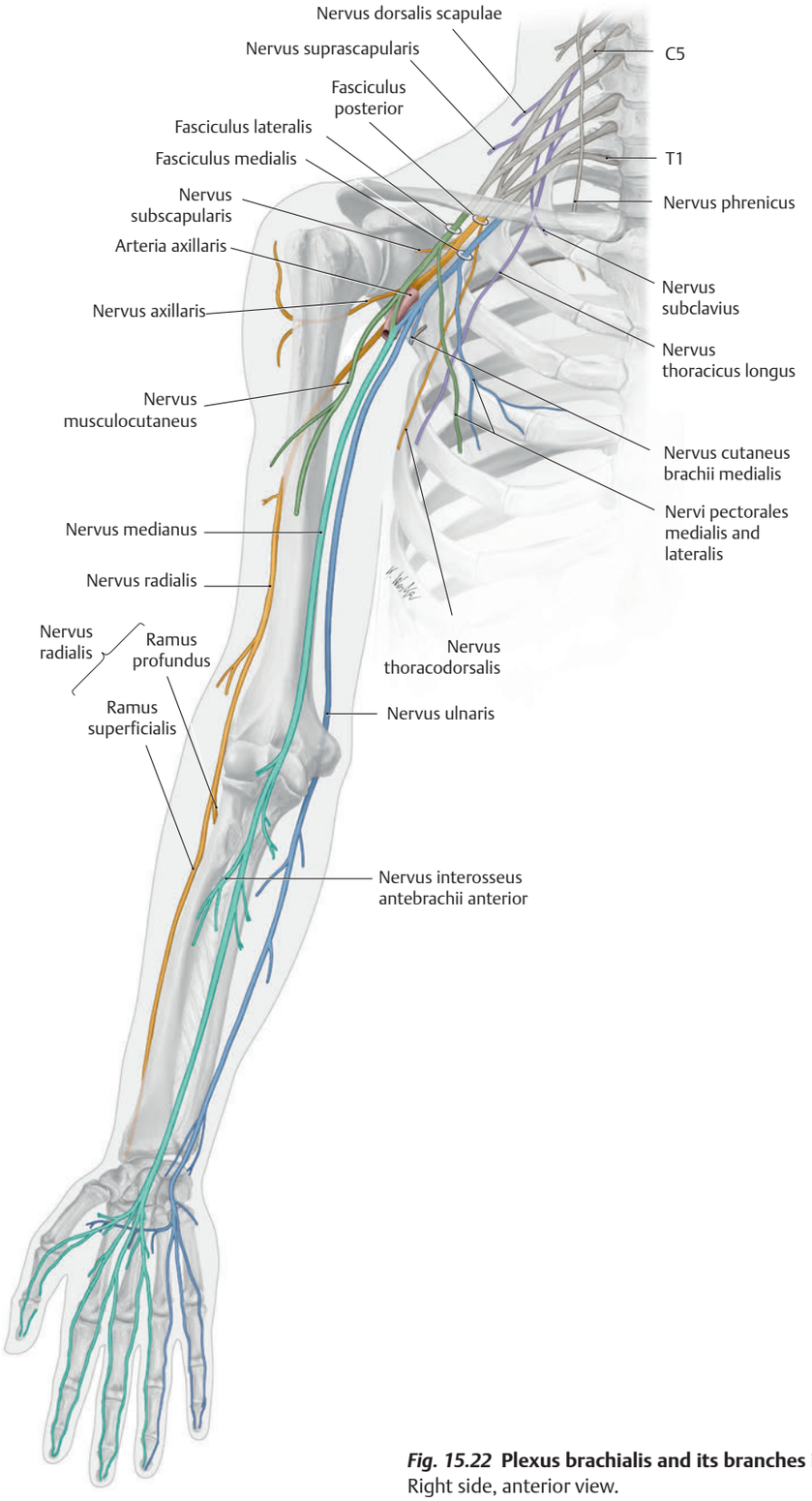


Table 15.1 **Nerves of the plexus brachialis**

Pars supraclavicularis				
Direct branches from the rami anteriores or trunci plexus				
		Nervus dorsalis scapulae		C4–C5
		Nervus suprascapularis		C4–C6
		Nervus subclavius		C5–C6
		Nervus thoracicus longus		C5–C7
Pars infraclavicularis				
Short and long branches from the fasciculi plexus				
	Fasciculus lateralis	Nervus pectoralis lateralis		C5–C7
		Nervus musculocutaneus		
		Nervus medianus	Radix lateralis	C6–C7
			Radix medialis	C8–T1
	Fasciculus medialis	Nervus pectoralis medialis		
		Nervus cutaneus antebrachii medialis		
		Nervus cutaneus brachii medialis		T1
		Nervus ulnaris		C7–T1
	Fasciculus posterior	Upper nervus subscapularis		C5–C6
		Nervus thoracodorsalis		C6–C8
		Lower nervus subscapularis		C5–C6
		Nervus axillaris		
		Nervus radialis		C5–T1

Fig. 15.22 **Plexus brachialis and its branches in the upper limb**
Right side, anterior view.

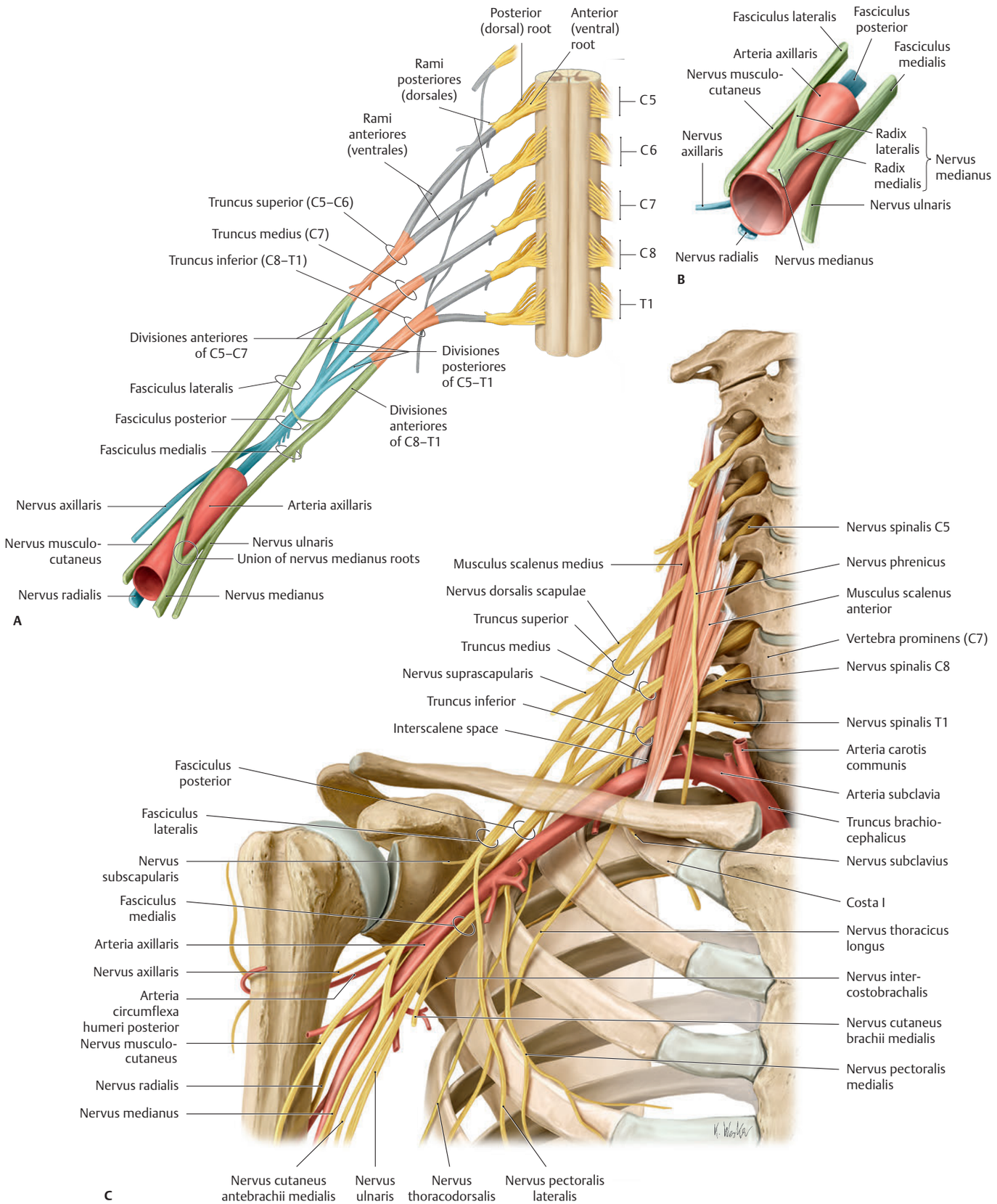


Fig. 15.23 **Plexus brachialis**
Right side, anterior view.
A Structure of the plexus brachialis.
B Division of the fasciculi into terminal branches.
C Course of the plexus brachialis, stretched for clarity

Skeleton Thoracis

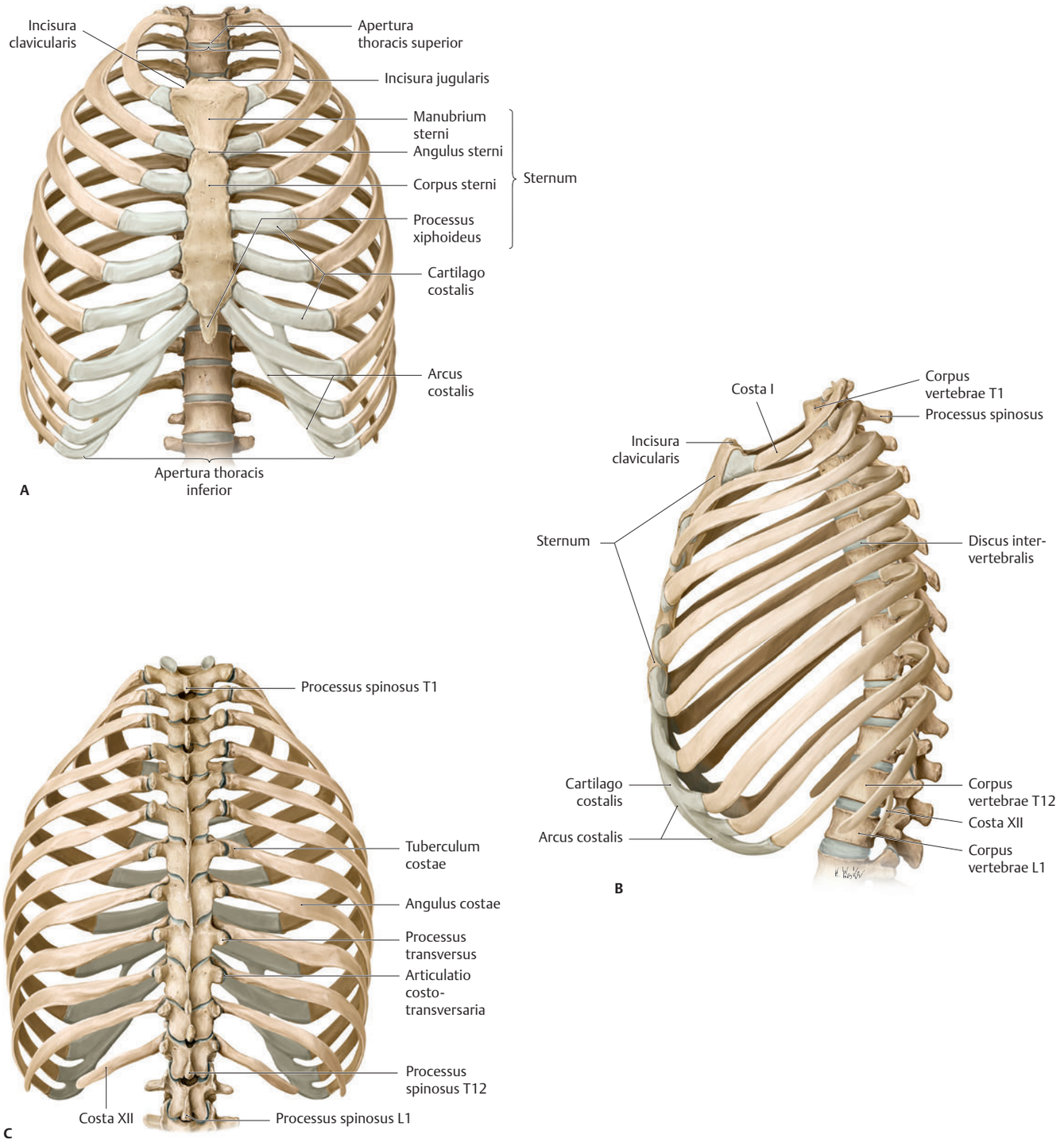


Fig. 15.24 **Skeleton thoracis**
A Anterior view. **B** Left lateral view.
C Posterior view.

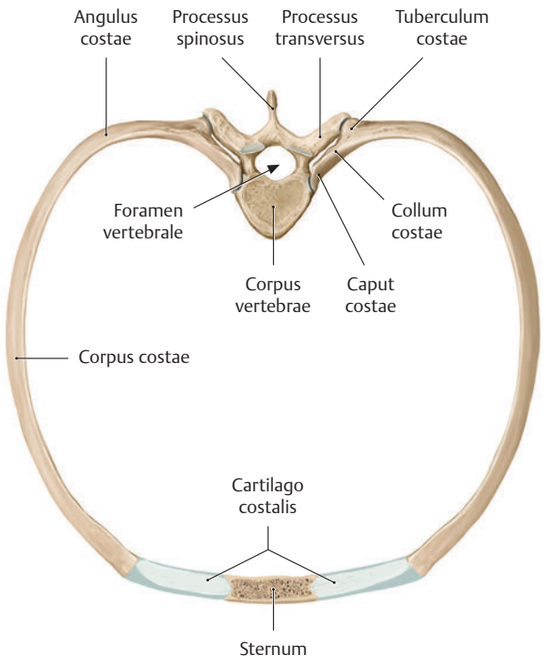


Fig. 15.25 **Structure of a thoracic segment**
Superior view of 6th rib pair.

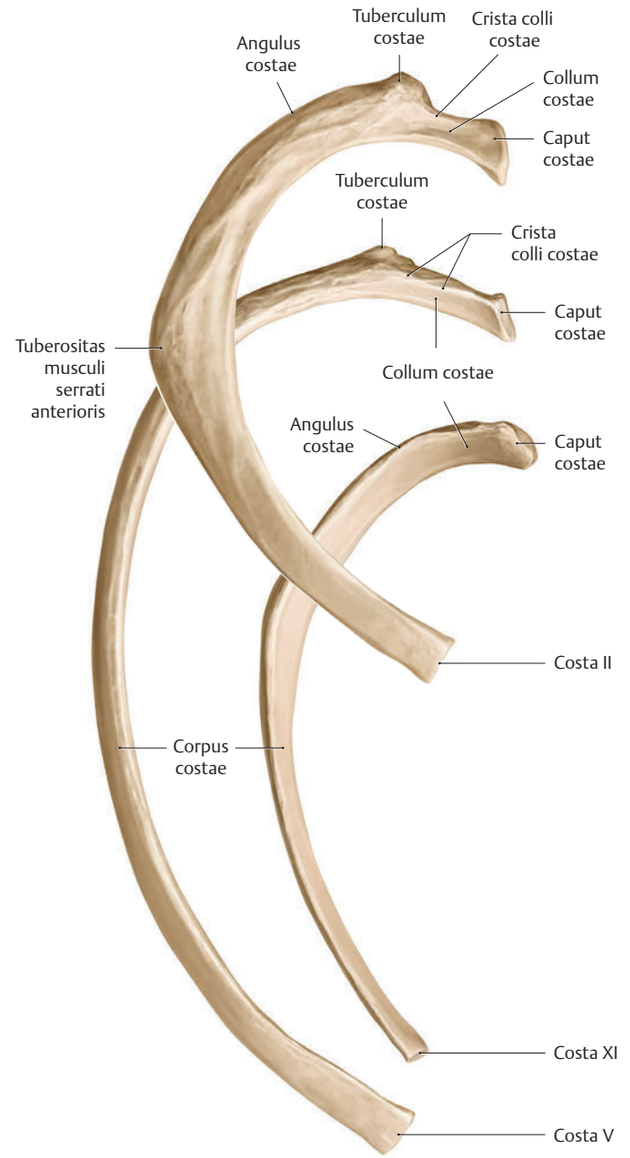


Fig. 15.26 **Ribs**
Right ribs, superior view.

Muscles & Neurovascular Topography of the Thoracic Wall

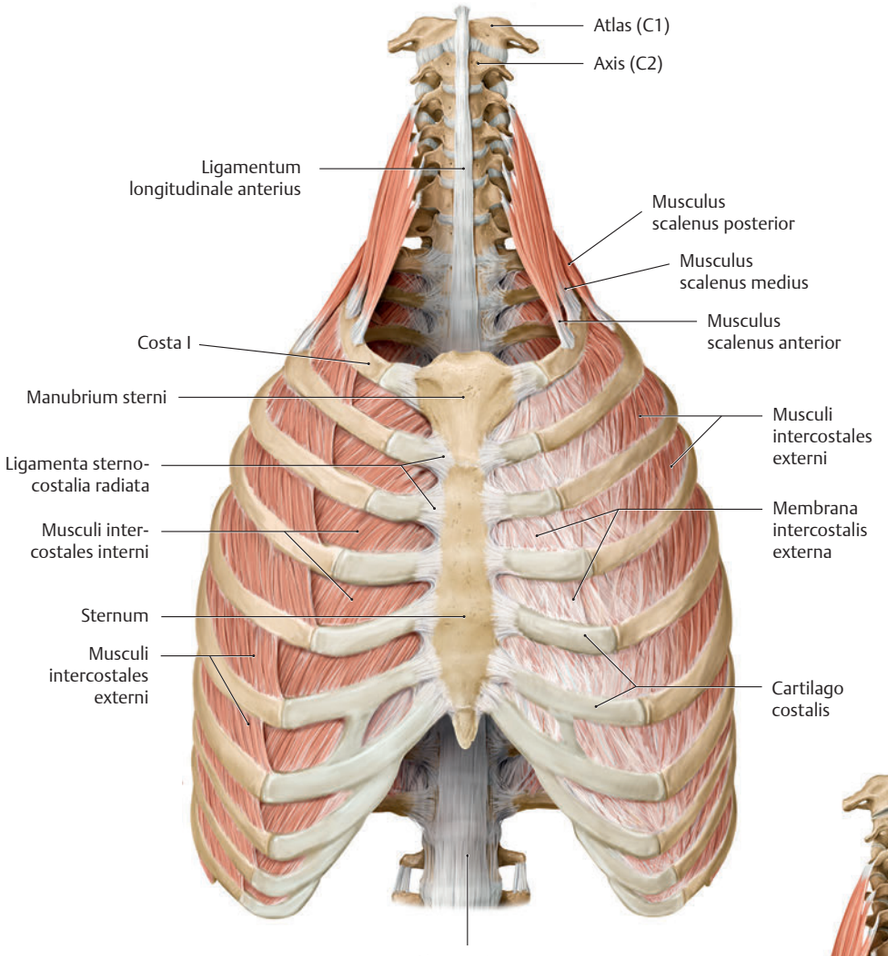


Fig. 15.27 **Muscles of the thoracic wall**
Anterior view. The musculi intercostales externi are replaced anteriorly by the Membrana intercostalis externa. The musculi intercostales interni are replaced posteriorly by the membrana intercostalis interna (removed in **Fig. 15.28**).

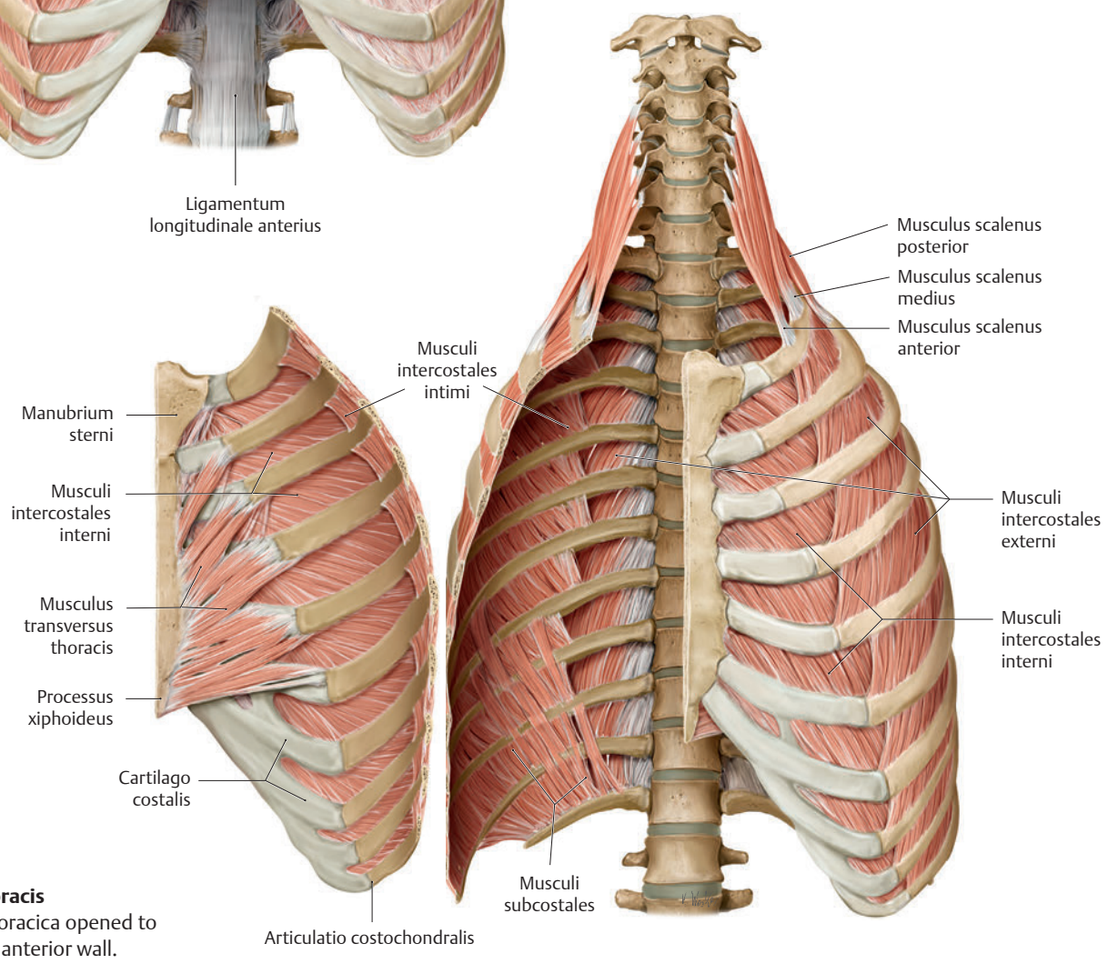


Fig. 15.28 **Transversus thoracis**
Anterior view with cavea thoracica opened to expose posterior surface of anterior wall.

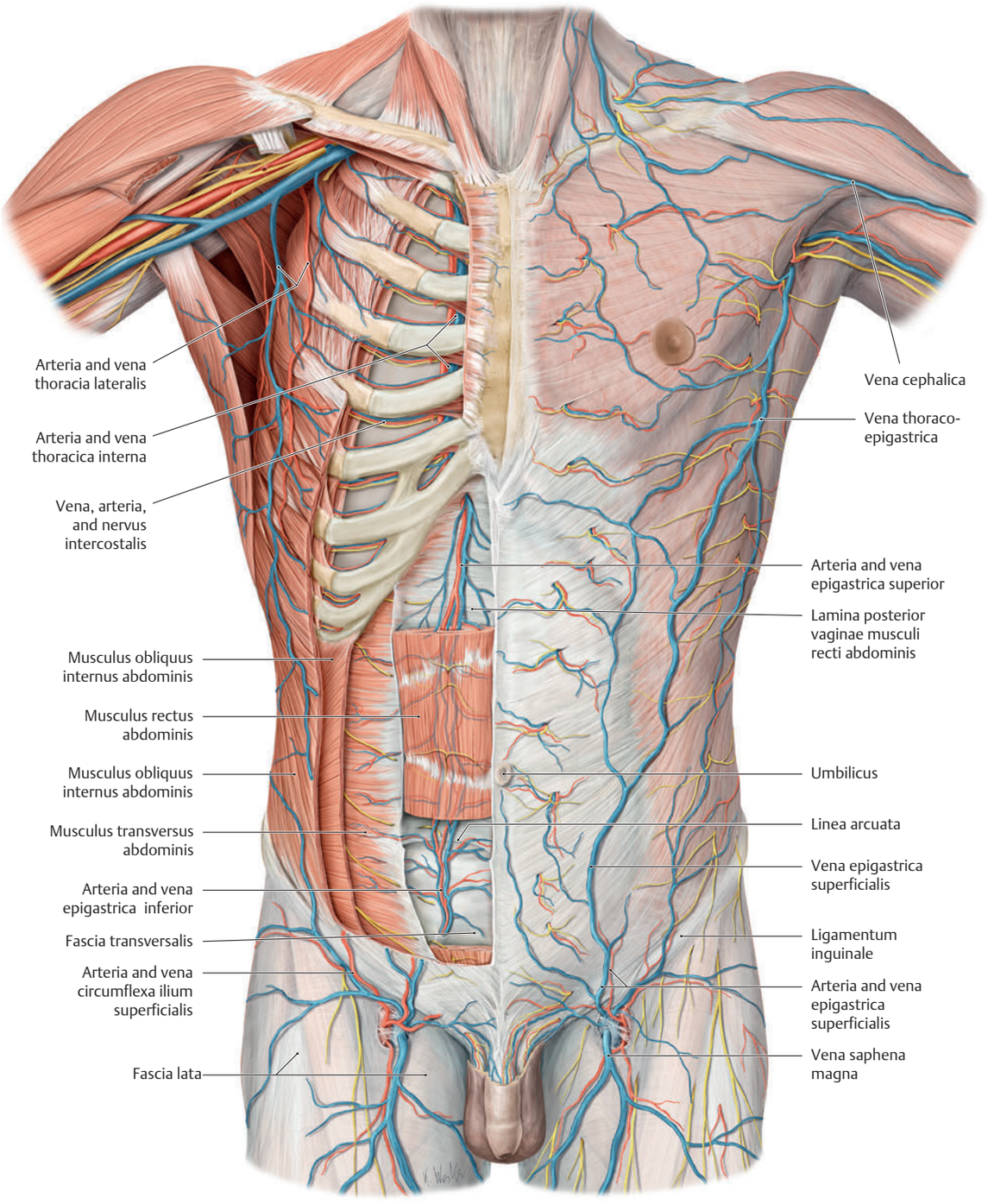


Fig. 15.29 **Neurovascular structures on the anterior side of the anterior trunk wall**
Anterior view. The superficial (subcutaneous) neurovascular structures are demonstrated on the left side of the trunk and the deep neurovascular structures on the right side.
Removed on right side: musculi pectorales major and minor, musculi obliqui externi and interni abdominis (partially removed), musculus rectus abdominis (partially removed or rendered transparent). The spatia intercostales have been exposed to display the course of the intercostal vessels and nerves.
Note: The intercostal vessels run in the sulcus costae. From superior to inferior they are vein, artery, and nerve.

Female Breast

The female breast, a modified sweat gland in the subcutaneous tissue layer, consists of glandular tissue, fibrous stroma, and fat. The breast extends from the 2nd to the 6th rib and is loosely attached to the pectoral, axillary, and superficial abdominal fascia by connective tissue. The breast is additionally supported by suspensory ligaments. An extension of the breast tissue into the axilla, the axillary tail, is often present.

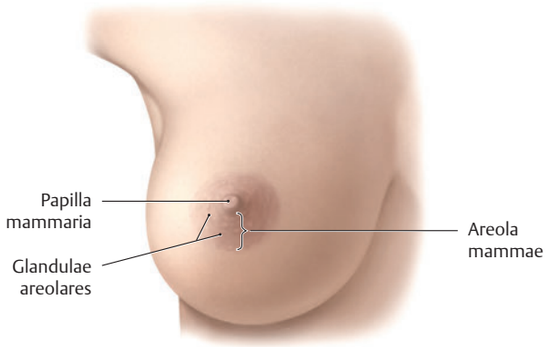


Fig. 15.30 **Female breast**
Right breast, anterior view.

Fig. 15.31 **Mammary ridges**
Rudimentary glandula mammaria form in both sexes along the mammary ridges. Occasionally, these may persist in humans to form accessory nipples (*polythelia*), although only the thoracic pair normally remains.

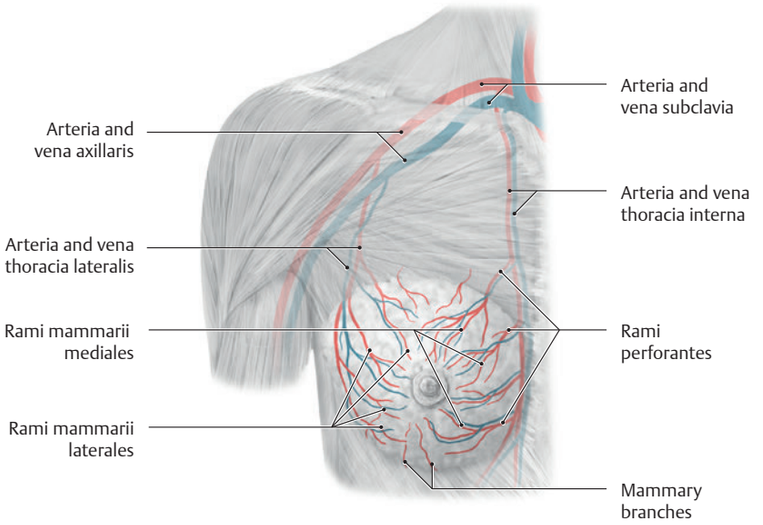


Fig. 15.32 **Blood supply to the breast**

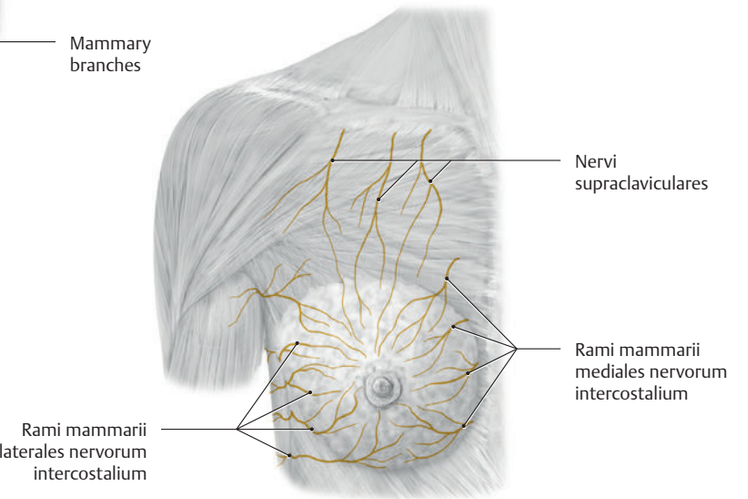


Fig. 15.33 **Sensory innervation of the breast**

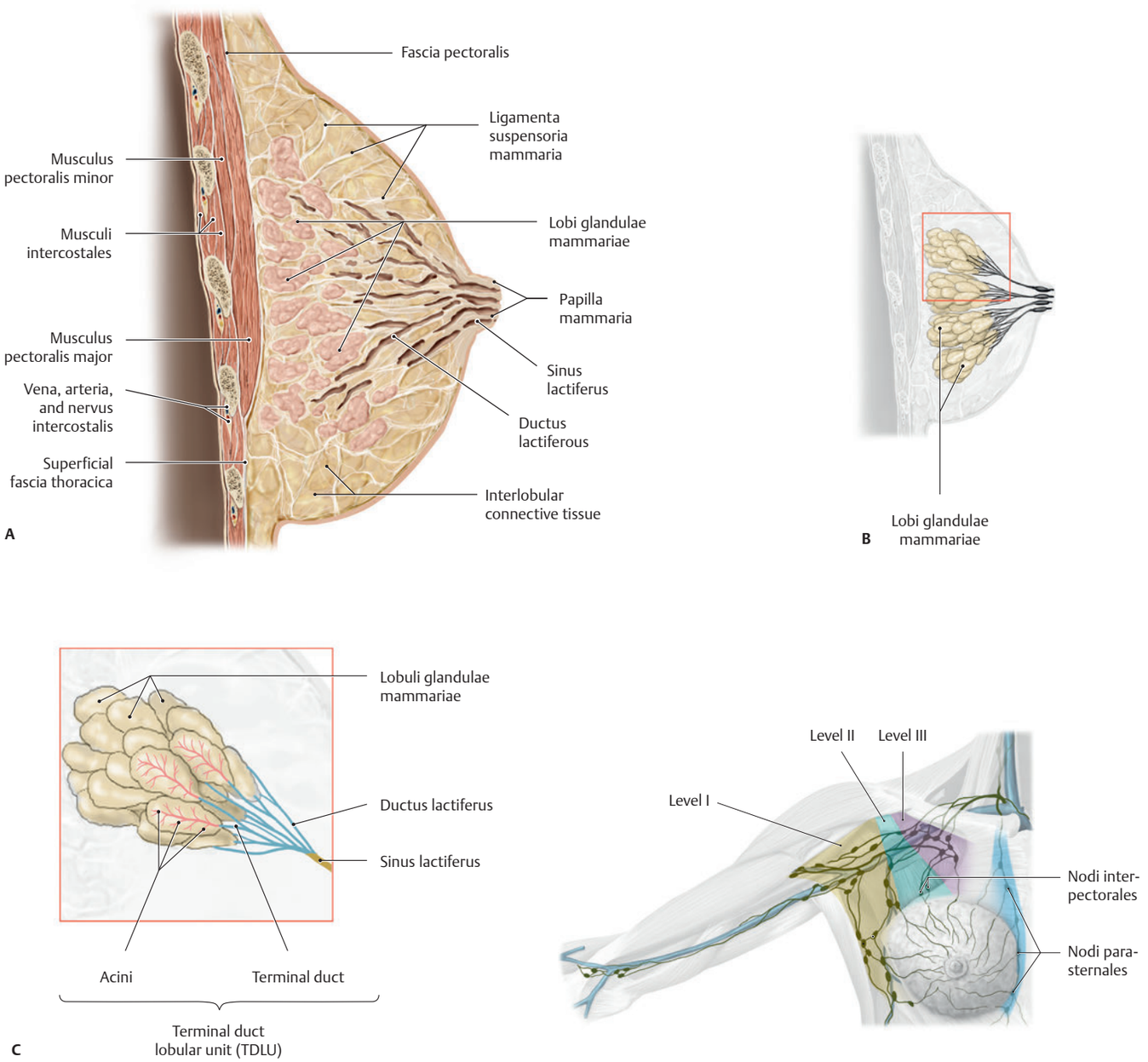


Fig. 15.34 **Structures of the breast**
A Sagittal section along linea mediclavicularis. **B** Duct system and portions of a lobe, sagittal section. In the nonlactating breast (shown here), the lobuli contain clusters of rudimentary acini. **C** Terminal duct lobular unit (TDLU). The clustered acini composing the lobulus empty into a terminal ductule; these structures are collectively known as the TDLU.
The glandular tissue is composed of 10 to 20 individual lobi, each with its own ductus lactiferus. The gland ducts open on the elevated papilla mammaria at the center of the pigmented areola. Just proximal to the duct opening is a dilated portion called the sinus lactiferus. Areolar elevations are the openings of the glandulae areolares (sebaceous). The glands and ductus lactiferi are surrounded by firm, fibrofatty tissue with a rich blood supply.
The most common type of breast cancer, invasive ductal carcinoma, arises from the lining of the ductus lactiferi. Typically it metastasizes through lymphatic channels, most abundantly to nodi lymphoidei axillares, but it may also travel to nodi supraclaviculares, the contralateral breast and the abdomen. Obstruction of the lymphatic drainage and fibrosis (shortening) of the ligamenta suspensoria can cause a leathery (peau d' orange) and dimpled appearance of the skin. Because the venae intercostales that drain the breast communicate with the azygos system and through that the plexus venosi vertebrales, breast cancer can spread to the vertebrae, cranium and brain. Elevation of the breast with contraction of the musculus pectoralis major suggests invasion of the retromammary space.

Fig. 15.35 **Lymphatic drainage of the breast**
The lymphatic vessels of the breast (not shown) are divided into three systems: superficial, subcutaneous, and deep. These drain primarily into the nodi lymphoidei axillares, which are classified based on their relationship to the pectoralis muscle as Levels I, II, and III. Level I is lateral to musculus pectoralis major; Level II is along this muscle; Level III is medial to it. The medial portion of the breast is drained by the nodi lymphoidei parasternales, which are associated with the internal thoracic vessels.

Diaphragma

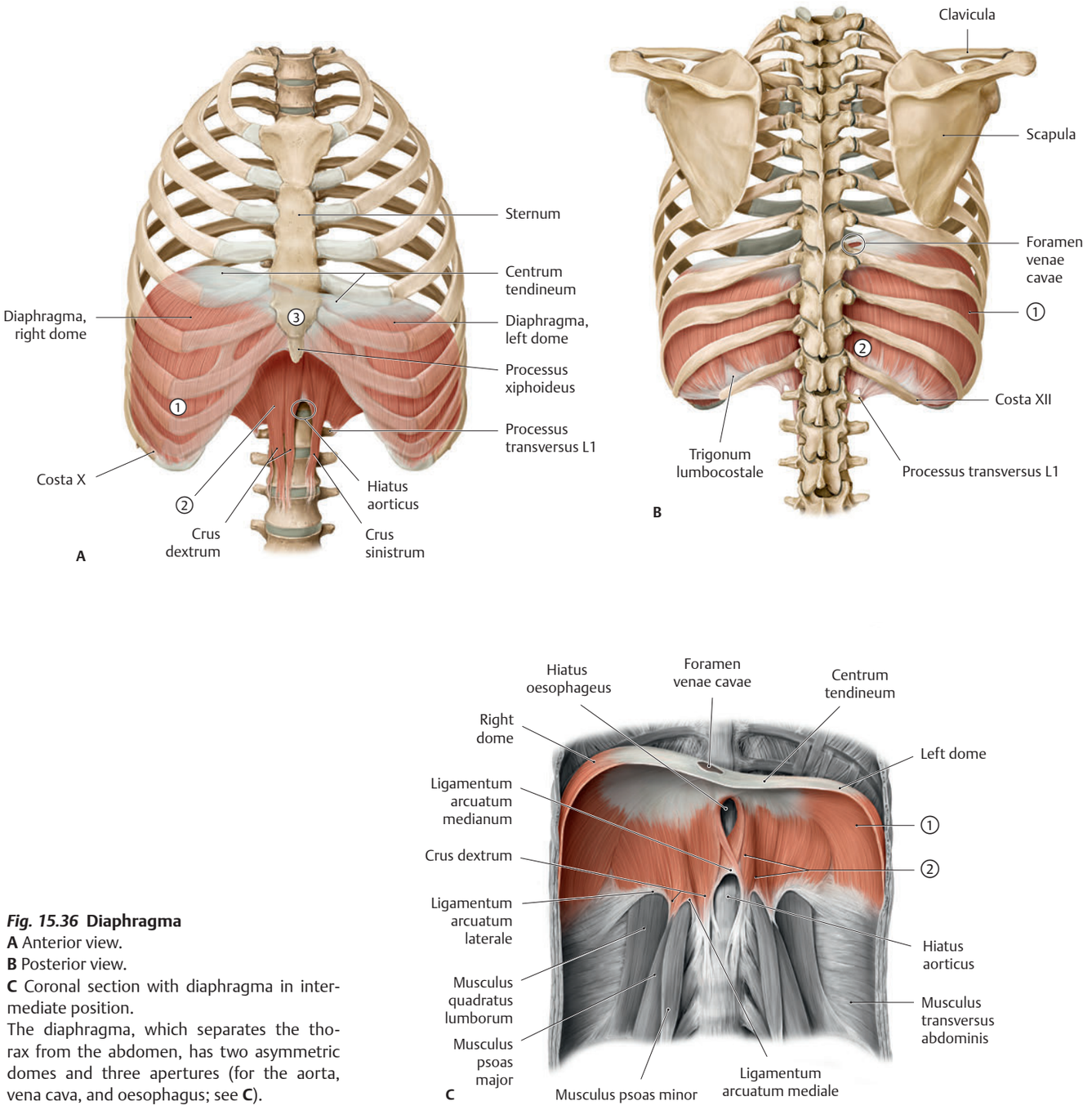


Fig. 15.36 **Diaphragma**
A Anterior view.
B Posterior view.
C Coronal section with diaphragma in intermediate position.
The diaphragma, which separates the thorax from the abdomen, has two asymmetric domes and three apertures (for the aorta, vena cava, and oesophagus; see **C**).

Table 15.2 **Diaphragma**

Muscle		Origin	Insertion	Innervation	Action
Diaphragma	① Pars costalis	Costae VII–XII (inner surface; lower margin of arcus costalis)	Centrum tendineum	Nervus phrenicus (C3–C5, plexus cervicalis)	Principal muscle of respiration (diaphragmatic and thoracic breathing); aids in compressing abdominal viscera (abdominal press)
	② Pars lumbalis	Medial part: corpora vertebrarum L1–L3, disci intervertebrales, and ligamentum longitudinale anterius as crura dextrum and sinistrum			
		Lateral parts: ligamenta arcuata laterale and mediale			
	③ Pars sternalis	Processus xiphoideus (posterior surface)			

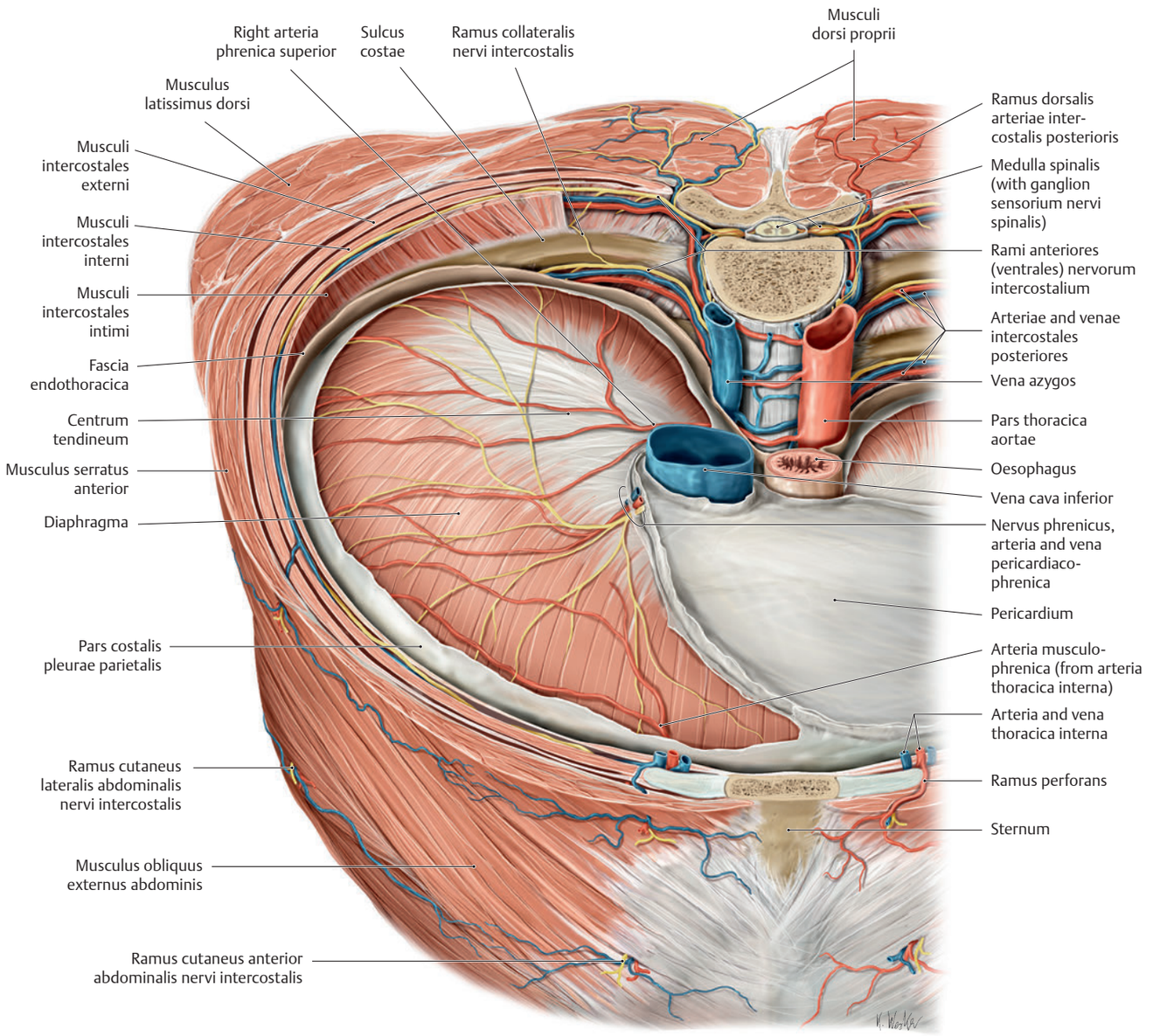


Fig. 15.37 **Thoracic section**
Transverse section, anterosuperior view.

Neurovasculature of the Diaphragma

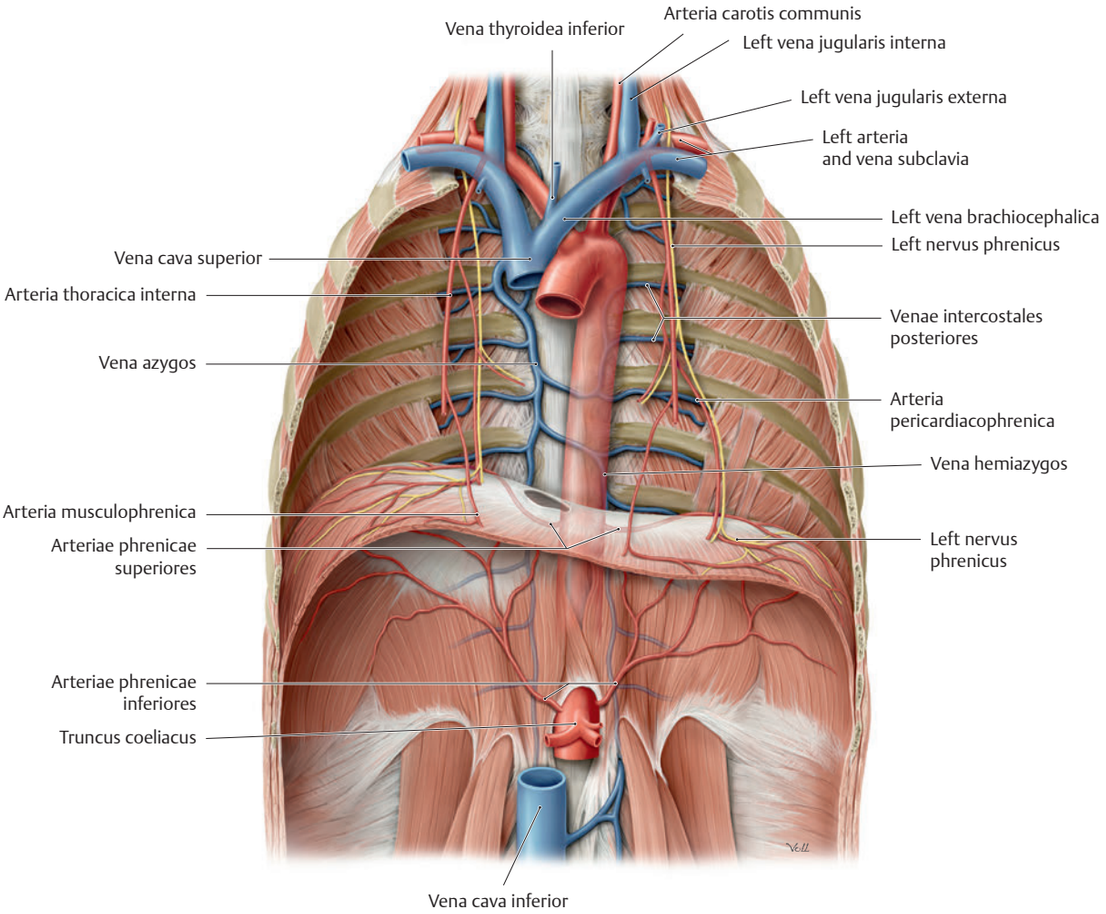


Fig. 15.38 **Neurovasculature of the diaphragma**
Anterior view of opened cavea thoracica.

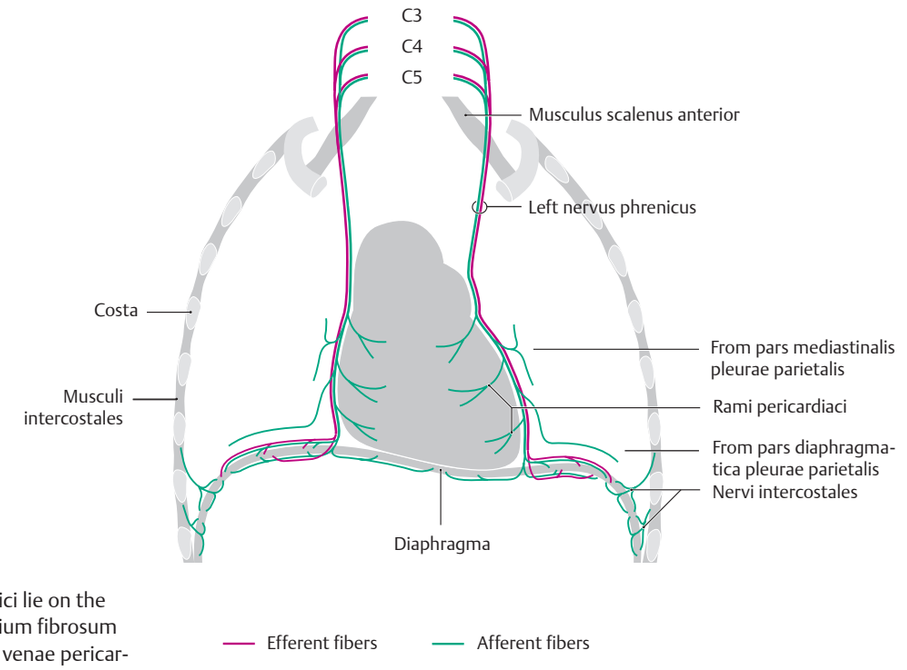
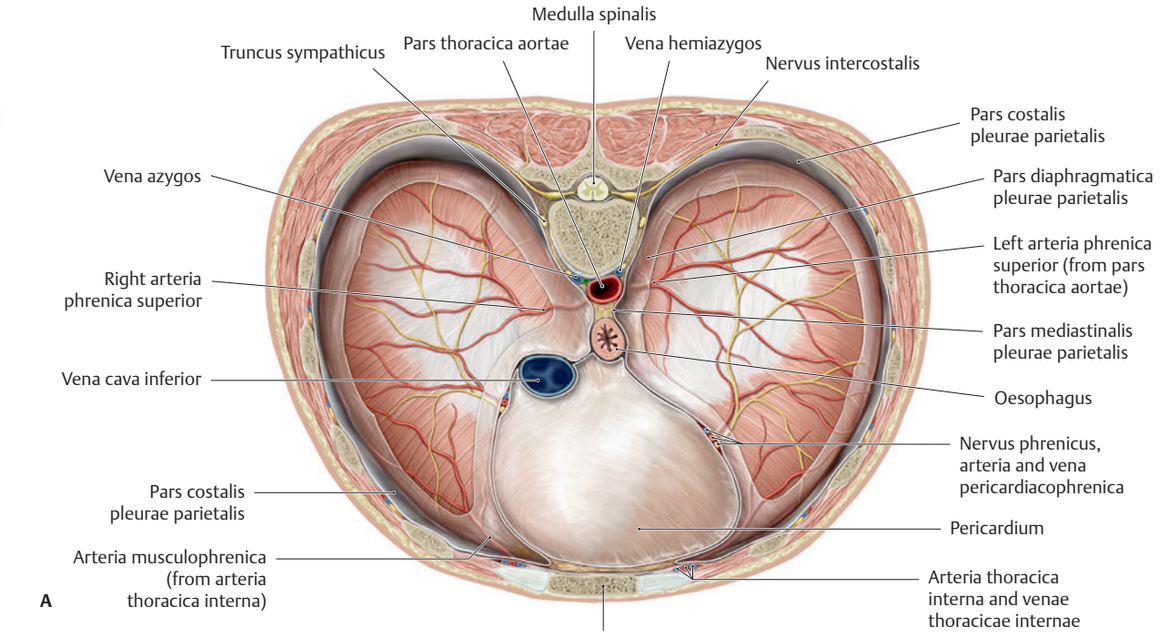


Fig. 15.39 **Innervation of the diaphragma**
Anterior view. The nervi phrenici lie on the lateral surfaces of the pericardium fibrosum together with the arteriae and venae pericardiacophrenicae. Note: The nervi phrenici also innervate the pericardium.

Table 15.3 **Blood vessels of the diaphragma**

Artery	Origin	Vein	Drainage
Arteriae phrenicae inferiores (chief blood supply)	Pars abdominis aortae; occasionally from truncus coeliacus	Venae phrenicae inferiores	Vena cava inferior
Arteriae phrenicae superiores	Pars thoracica aortae	Venae phrenicae superiores	Vena azygos (right side), vena hemiazygos (left side)
Arteriae pericardiacophrenicae	Arteriae thoracicae internae	Venae pericardiacophrenicae	Venae thoracicae internae or Venae brachiocephalicae
Arteriae musculophrenicae		Venae musculophrenicae	Venae thoracicae internae



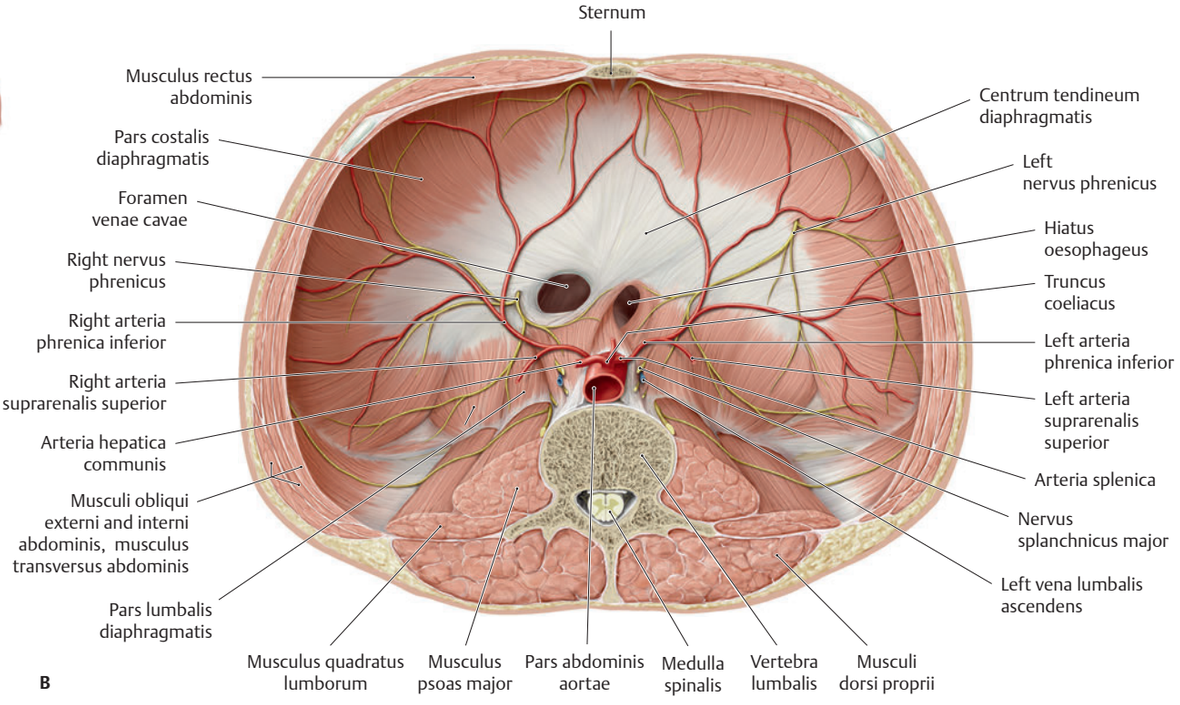


Fig. 15.40 **Arteries and nerves of the diaphragma**
A Superior view.
B Inferior view. *Removed:* Peritoneum parietale.
Note: The margins of the diaphragma receive sensory innervation from the lowest nervi intercostales.

Divisions of the Cavitas Thoracis & Lymphatics

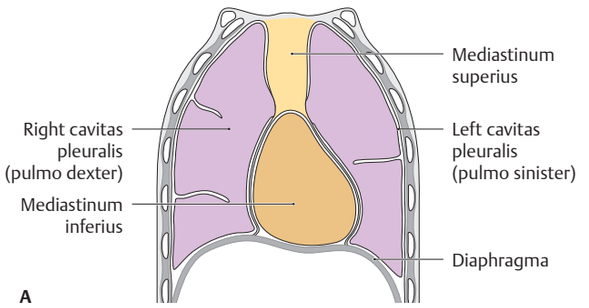


Table 15.4 **Major structures of the cavitas thoracica**

Mediastinum	Mediastinum superius		Thymus, great vessels, trachea, oesophagus, and ductus thoracicus
	Mediastinum inferius	Mediastinum anterius	Thymus (especially in children)
		Mediastinum medius	Heart, pericardium, and roots of great vessels
		Mediastinum posterius	Pars thoracica aortae, ductus thoracicus, oesophagus, and azygos venous system
Cavitates pleurales	Right cavitas pleuralis		Pulmo dexter
	Left cavitas pleuralis		Pulmo sinister

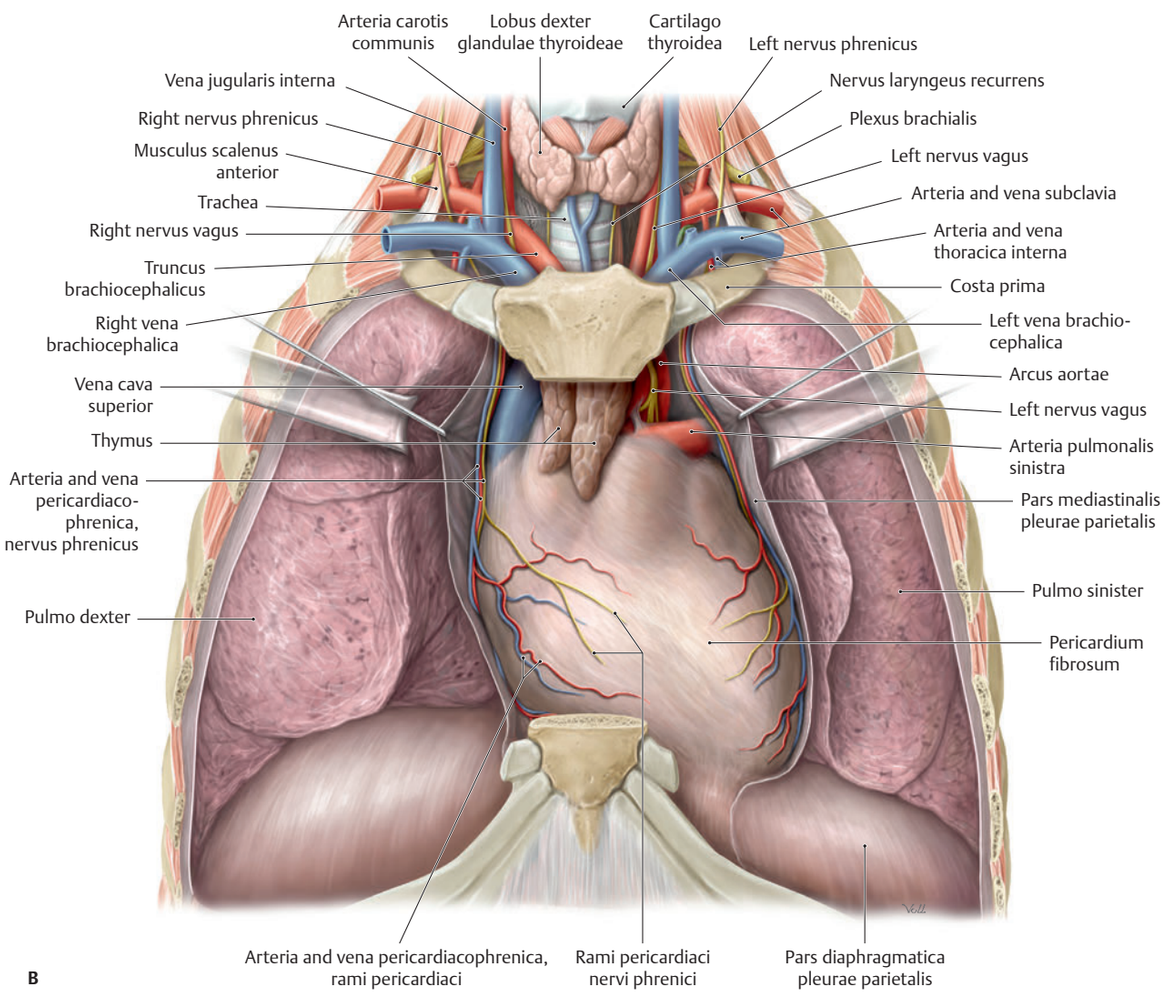


Fig. 15.41 **Cavitas thoracica**
Coronal section, anterior view.
A Divisions of the cavitas thoracica. The cavitas thoracica is divided into three large spaces, the mediastinum (p. 418) and the two cavitates pleurales (p. 432).
B Opened cavitas thoracica. *Removed:* Thoracic wall; connective tissue of mediastinum anterius

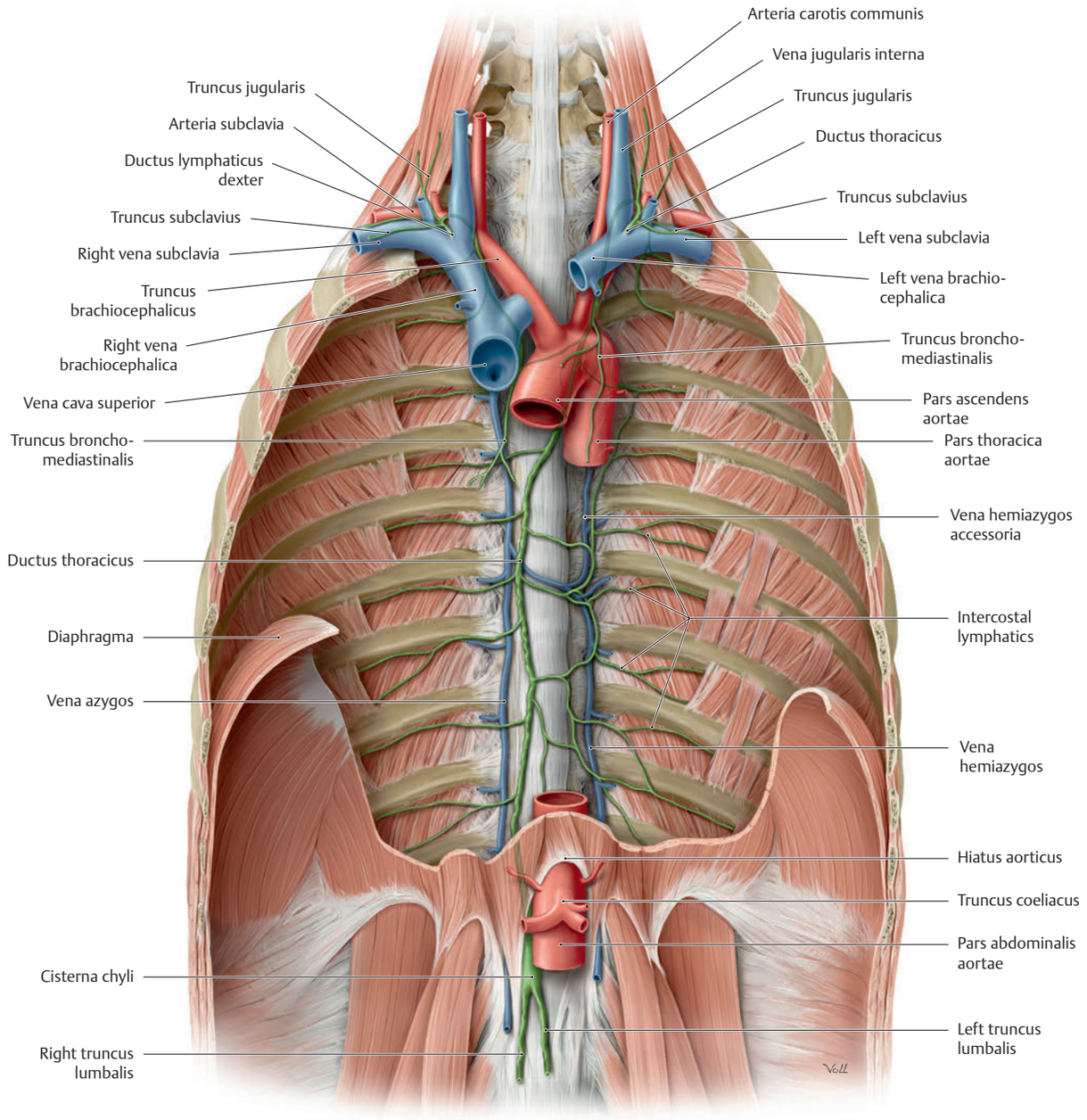


Fig. 15.42 **Trunci lymphatici in the thorax**
Anterior view of opened thorax.
The body's chief lymph vessel is the ductus thoracicus. Beginning in the abdomen at the level of L1 as the *cisterna chyli*, the ductus thoracicus empties into the junction of the left venae jugularis interna and subclavia. The ductus lymphaticus dexter drains to the right junction of the venae jugularis interna and subclavia.

Thoracic Vasculature

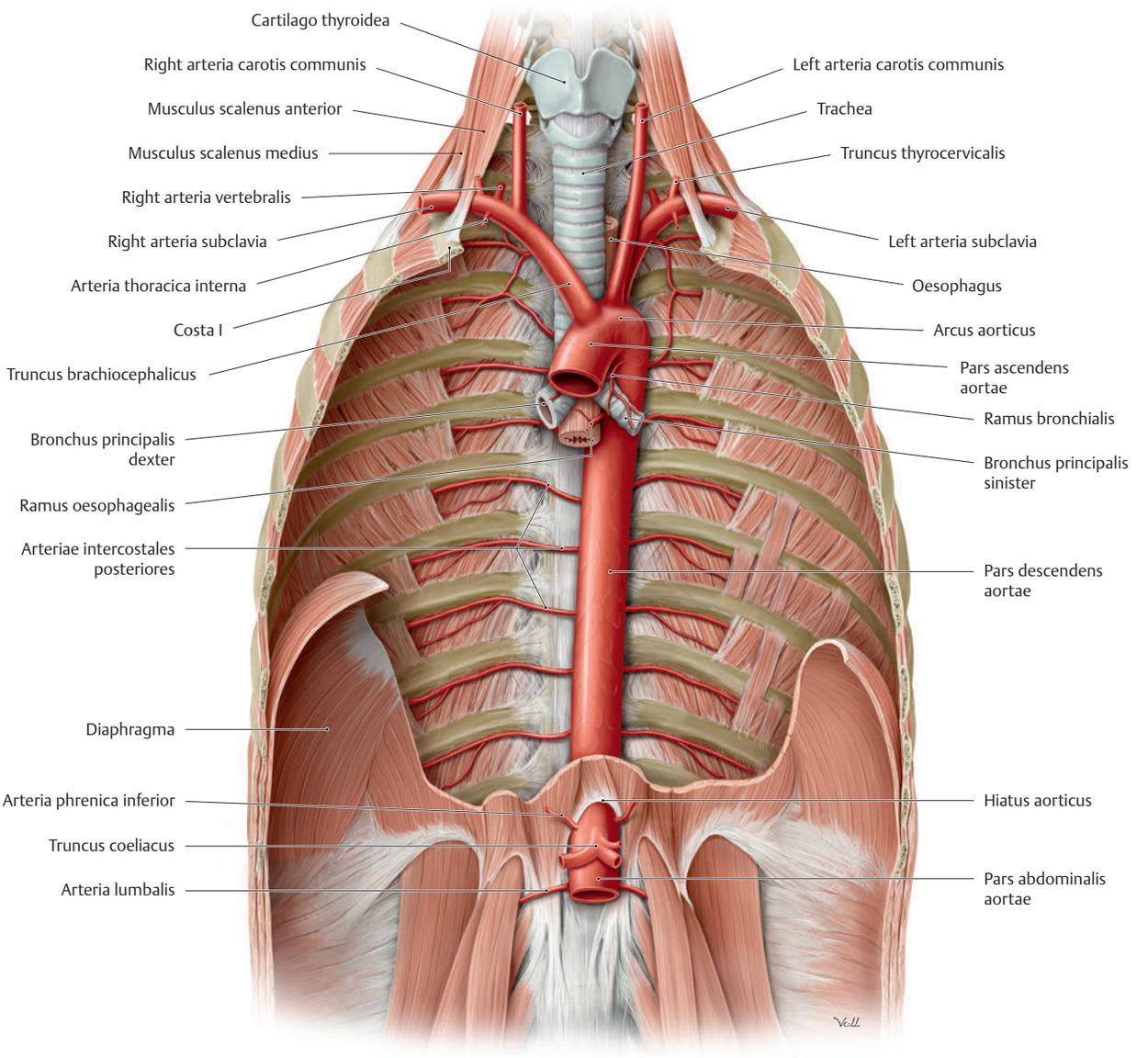
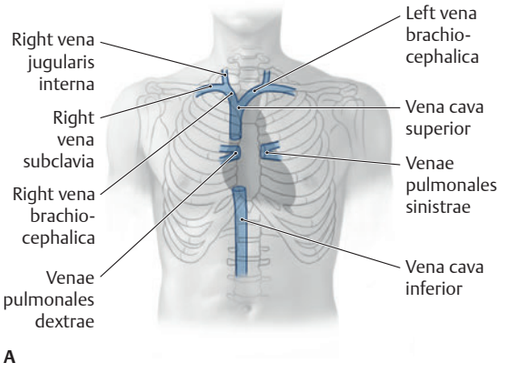


Fig. 15.43 **Pars thoracica aortae in situ**
Anterior view. Removed: Heart, lungs, and portions of the diaphragma.

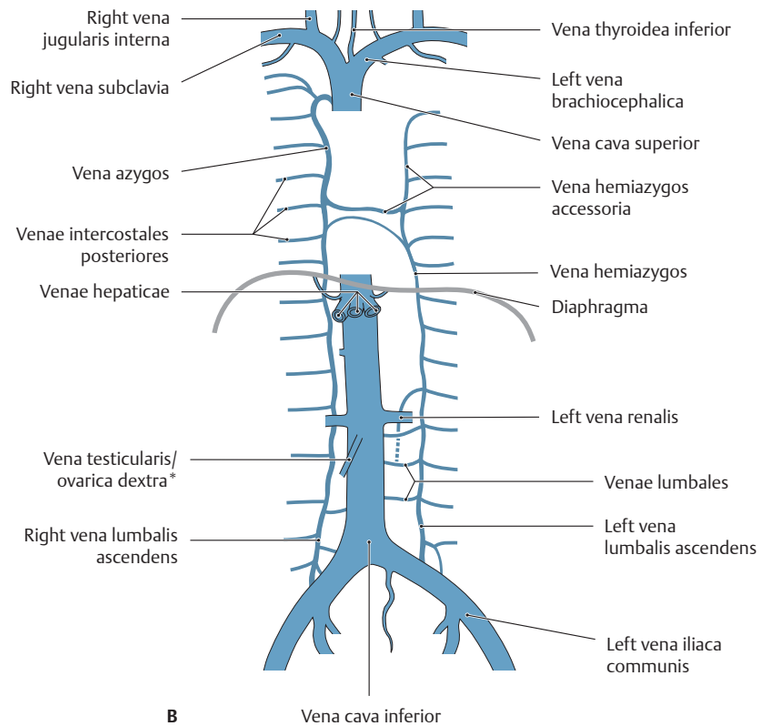


A

Table 15.5 **Thoracic tributaries of the vena cava superior**

Major vein	Tributaries		Region drained
Venae brachiocephalicae	Vena thyroidea inferior		Oesophagus, trachea, glandula thyroidea
	Venae jugulares internae		Head, neck, upper limb
	Venae jugulares externae		
	Venae subclaviae		
	Venae intercostales supremae		
	Venae pericardiacae		
	Vena intercostalis superior sinistra		
Azygos system (left side: vena hemiazygos accessoria; right side: vena azygos)	Visceral branches		Trachea, bronchi, oesophagus
	Parietal branches	Venae intercostales posteriores	Inner chest wall and diaphragm
		Venae phrenicae superiores	
		Vena intercostalis superior dextra	
Vena thoracica interna	Venae thymicae		Thymus
	Venae mediastinales		Mediastinum posterius
	Venae intercostales anteriores		Anterior chest wall
	Vena pericardiacophrenica		Pericardium
	Vena musculophrenica		Diaphragma

Note: Structures of the mediastinum superius may also drain directly to the venae brachiocephalicae via the venae tracheales, oesophageales, and mediastinales.



B

Fig. 15.44 **Vena cava superior**
Anterior view. **A** Projection of venae cavae onto chest. **B** Veins of the cavitas thoracica.

Nerves of the Cavitas Thoracis

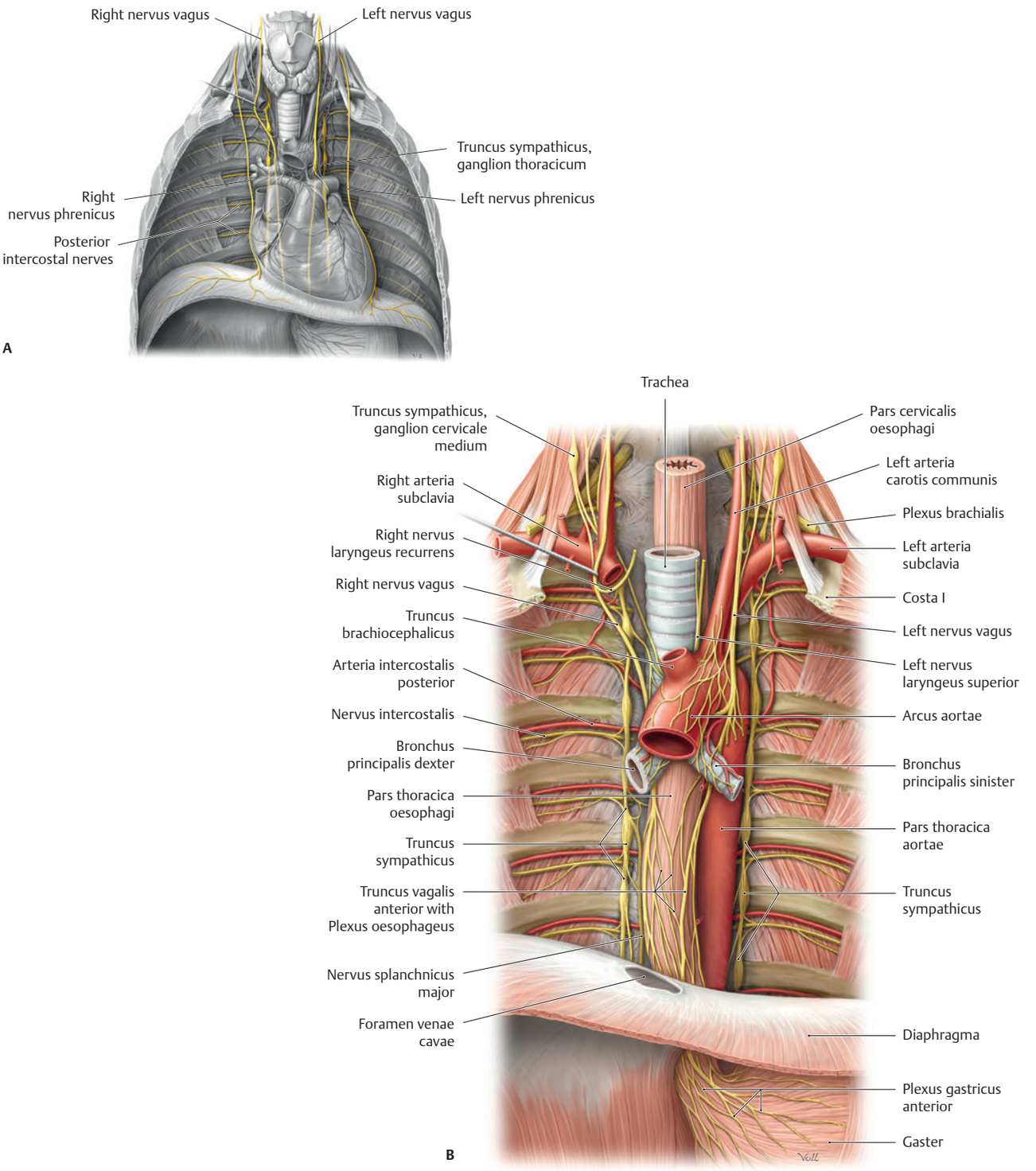


Fig. 15.45 **Nerves in the thorax**
Anterior view of opened thorax.
Thoracic innervation is mostly autonomic, arising from the paravertebral trunci sympathici and parasympathetic nervi vagi. There are two exceptions: the nervi phrenici innervate the pericardium and diaphragma and the nervi intercostales innervate the thoracic wall.

A Thoracic innervation.
B Nerves of the thorax in situ. *Note:* The nervi laryngei recurrentes have been slightly anteriorly retracted; normally, they occupy the groove between the trachea and the oesophagus, making them vulnerable during glandula thyroidea surgery.

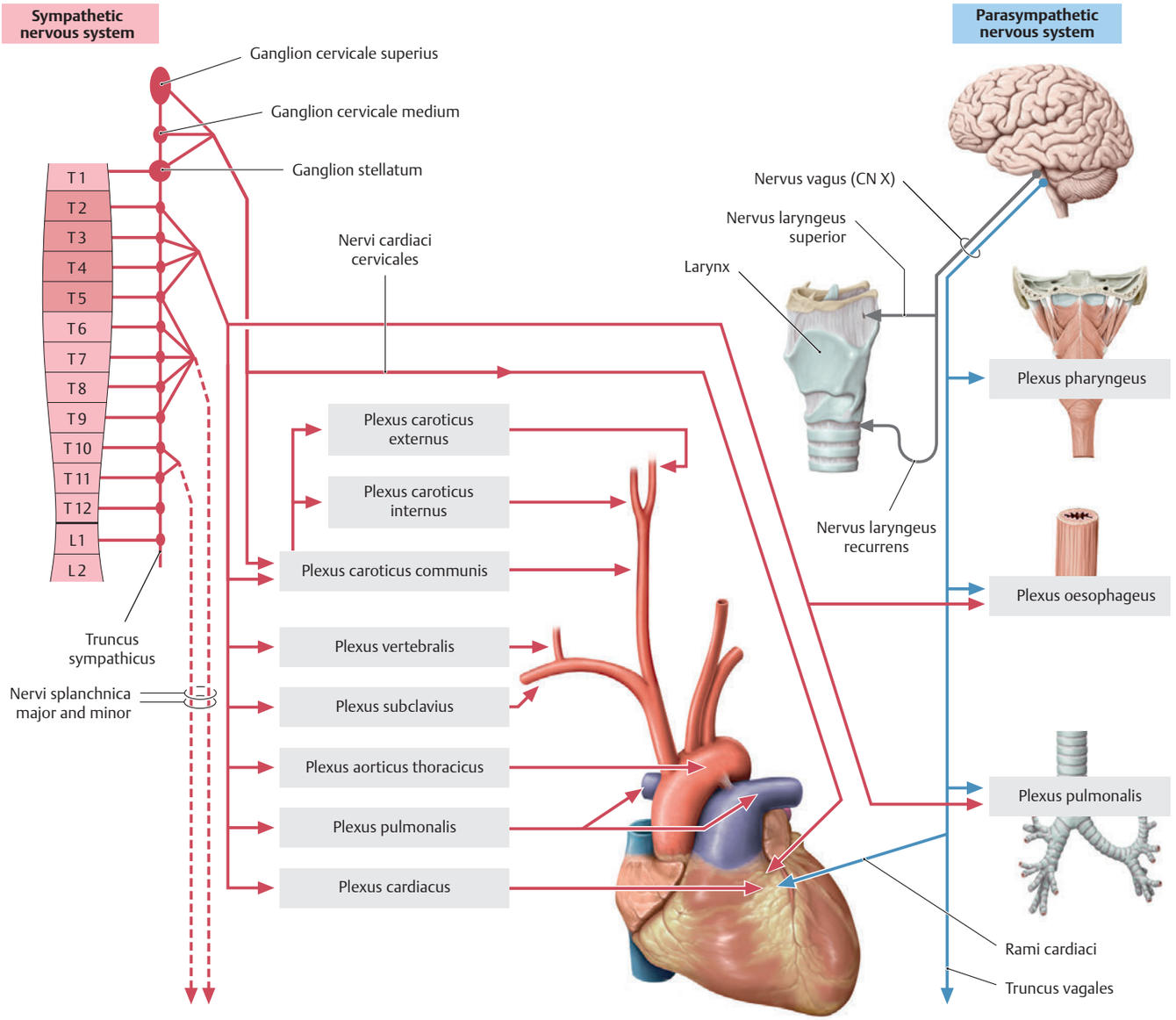


Fig. 15.46 **Sympathetic and parasympathetic nervous systems in the thorax**
The autonomic nervous system innervates smooth muscle, cardiac muscle, and glands. It is subdivided into the sympathetic (red) and parasympathetic (blue) nervous systems, which together regulate blood flow, secretions, and organ function.

Table 15.6 **Peripheral sympathetic nervous system**

Origin of preganglionic fibers*	Ganglion cells	Course of postganglionic fibers	Target
Medulla spinalis	Truncus sympathicus	Follow nervi intercostales	Blood vessels and glands in chest wall
		Accompany intrathoracic aa.	Visceral targets
		Gather in nervi splanchnici major and minor	Abdomen

*The axons of preganglionic neurons exit the medulla spinalis via the radices anteriores and synapse with *post*ganglionic neurons in the sympathetic ganglia.

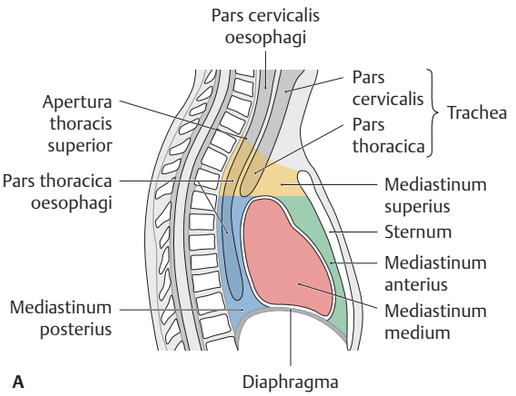
Table 15.7 **Peripheral parasympathetic nervous system**

Origin of preganglionic fibers	Course of preganglionic motor axons*		Target
Truncus encephali	Nervus vagus (CN X)	Rami cardiaci	Plexus cardiacus
		Rami oesophagei	Plexus oesophageus
		Rami tracheales	Trachea
		Rami bronchiales	Plexus pulmonalis (bronchi, pulmonary vessels)

*The ganglion cells of the parasympathetic nervous system are scattered in microscopic groups in their target organs. The nervus vagus thus carries the *pre*ganglionic motor axons to these targets.
CN, nervus cranialis (cranial nerve).

Mediastinum: Overview

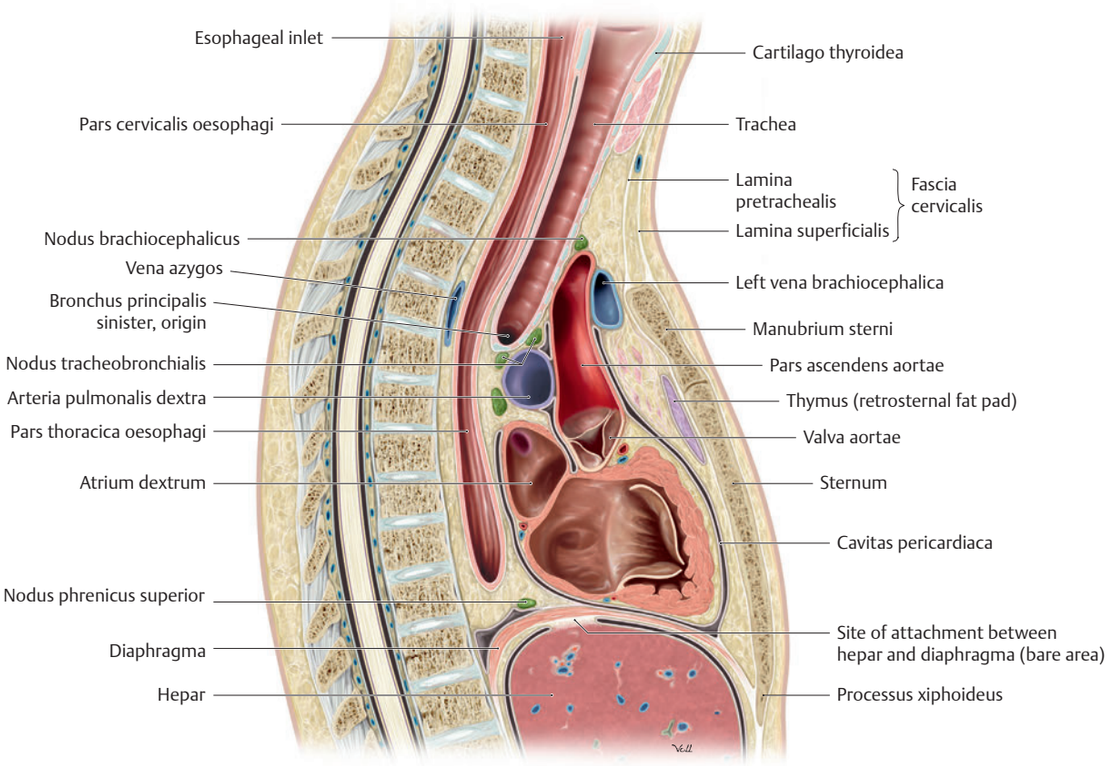
The mediastinum is the space in the thorax between the pleural sacs of the lungs. It is divided into two parts: superius and inferius. The mediastinum inferius is further divided into anterior, middle, and posterior portions.



A

Table 15.8 **Contents of the mediastinum**

	Mediastinum superius	Mediastinum inferius		
		Anterius	*Medium*	*Posterius*
Organs	• Thymus • Trachea • Oesophagus	• Thymus	• Heart • Pericardium	• Oesophagus
Arteries	• Arcus aorticus • Truncus brachiocephalicus • Left arteria carotis communis • Left arteria subclavia	• Smaller vessels	• Pars ascendens aortae • Truncus pulmonalis and rami pulmonales • Arteriae pericardiacophrenicae	• Pars thoracica aortae and rami
Veins and lymph vessels	• Vena cava superior • Venae brachiocephalicae • Ductus thoracicus	• Smaller vessels, lymphatics, and lymph nodes	• Vena cava superior • Vena azygos • Venae pulmonales • Venae pericardiacophrenicae	• Vena azygos • Vena hemiazygos • Ductus thoracicus
Nerves	• Nervi vagi • Left nervus laryngeus recurrens • Rami cardiaci • Nervi phrenici	• None	• Nervi phrenici	• Nervi vagi



B

Fig. 15.47 **Divisions of the mediastinum**
A Schematic. **B** Midsagittal section, right lateral view.

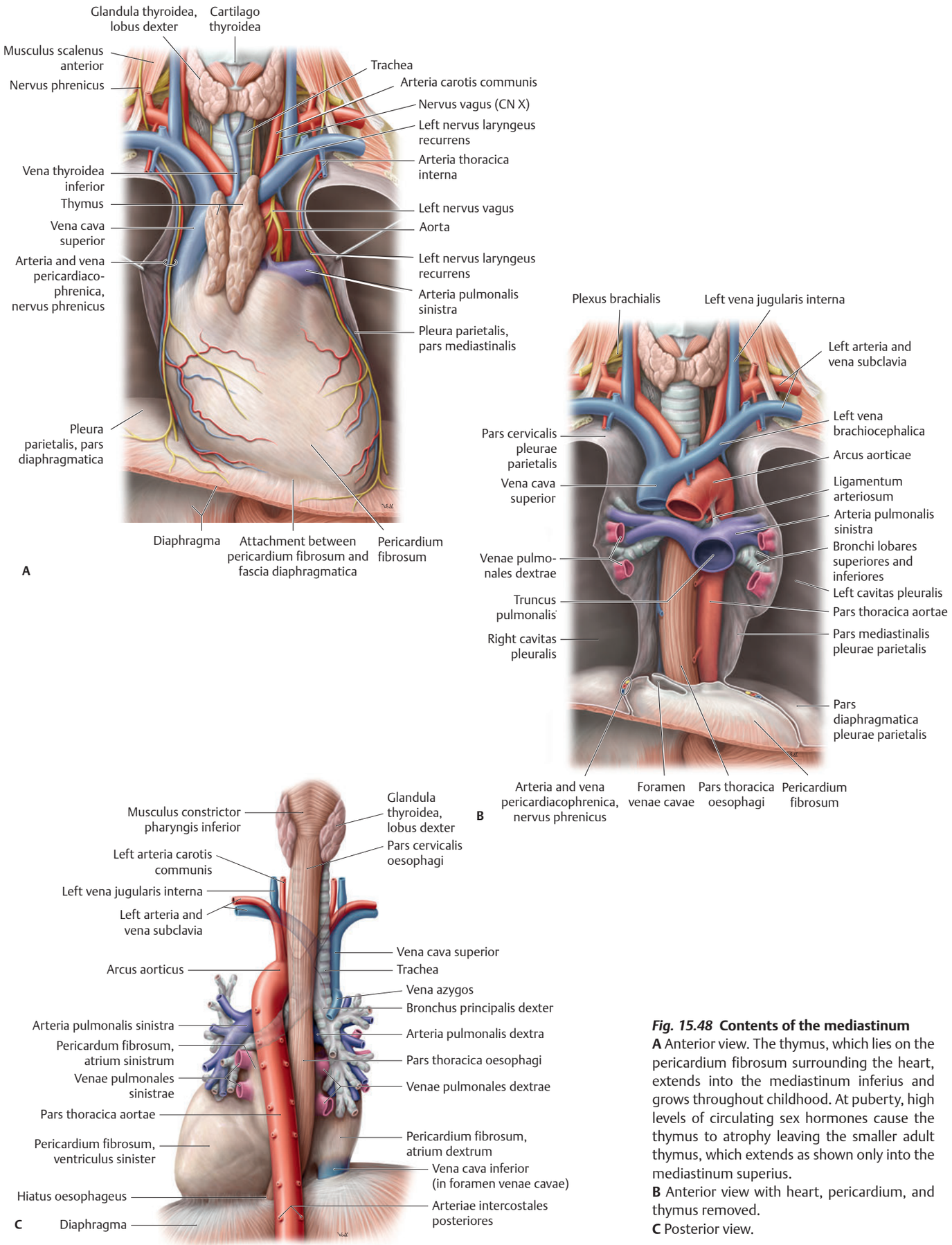


Fig. 15.48 **Contents of the mediastinum**
A Anterior view. The thymus, which lies on the pericardium fibrosum surrounding the heart, extends into the mediastinum inferius and grows throughout childhood. At puberty, high levels of circulating sex hormones cause the thymus to atrophy leaving the smaller adult thymus, which extends as shown only into the mediastinum superius.
B Anterior view with heart, pericardium, and thymus removed.
C Posterior view.

Mediastinum: Structures

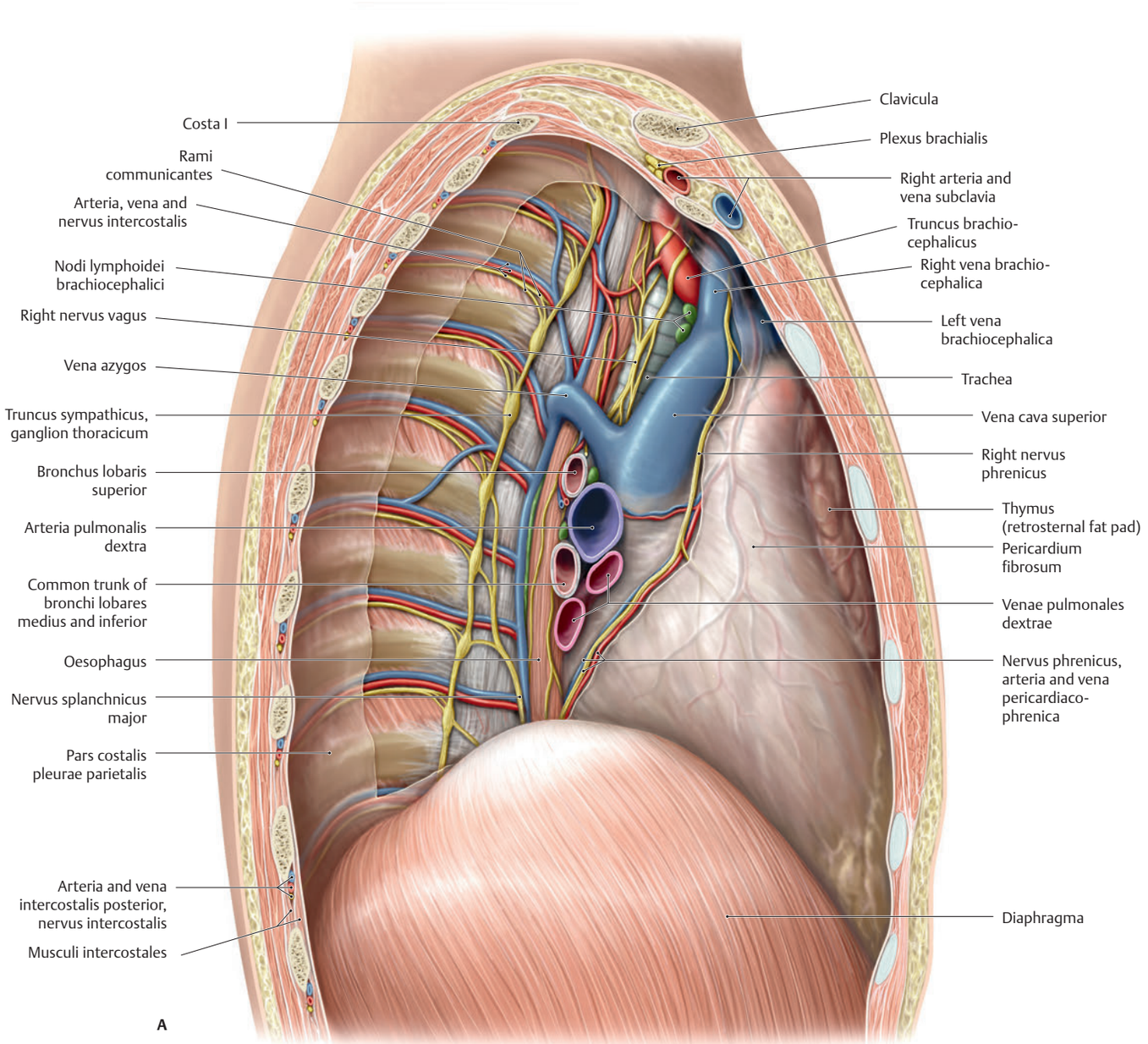
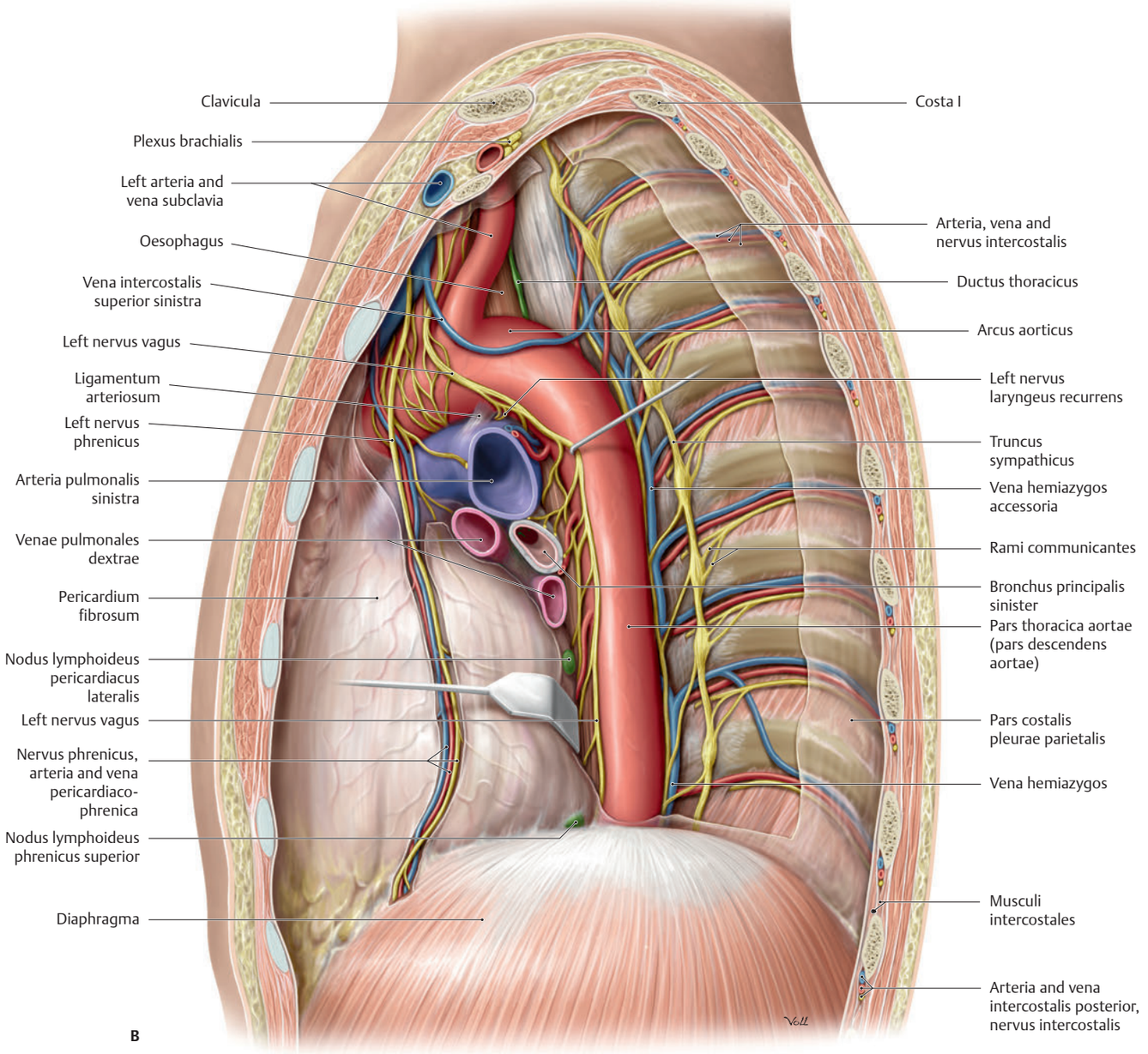


Fig. 15.49 **Mediastinum**
A Right lateral view, parasagittal section. Note the many structures passing between the superior and inferior (middle and posterior) mediastinum.



B Left lateral view, parasagittal section. Removed: Pulmo sinister and pleura parietalis. *Revealed:* Posterior mediastinal structures.

Heart: Surfaces & Chambers

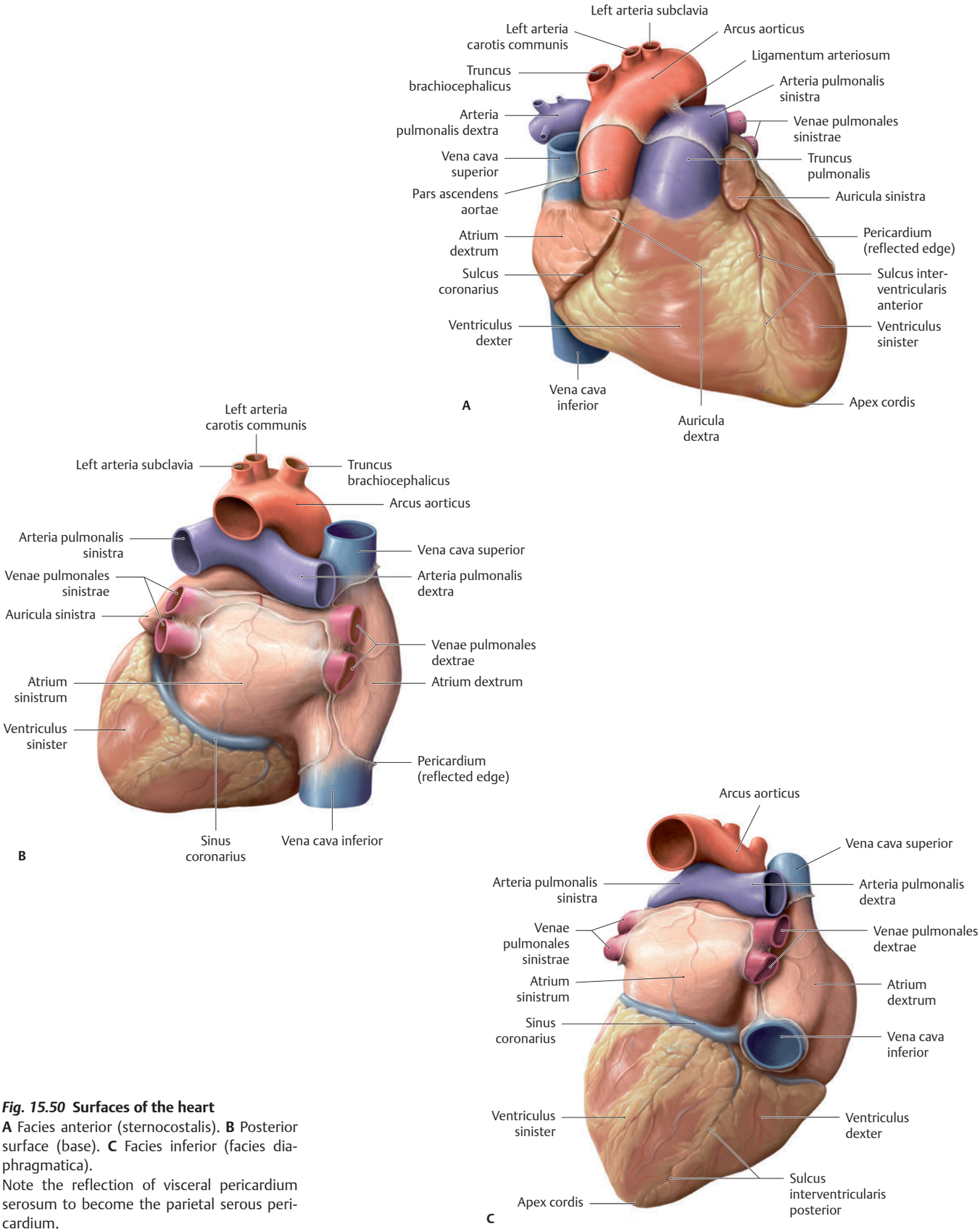
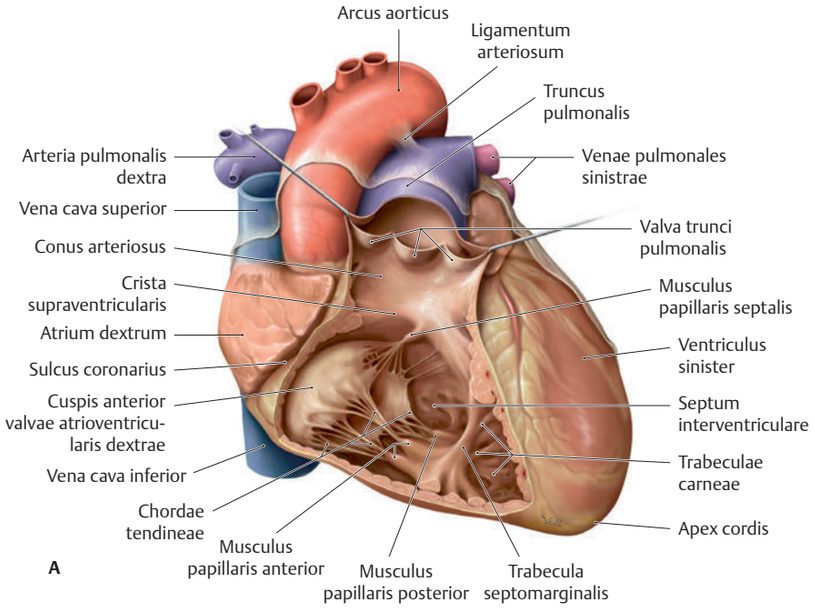
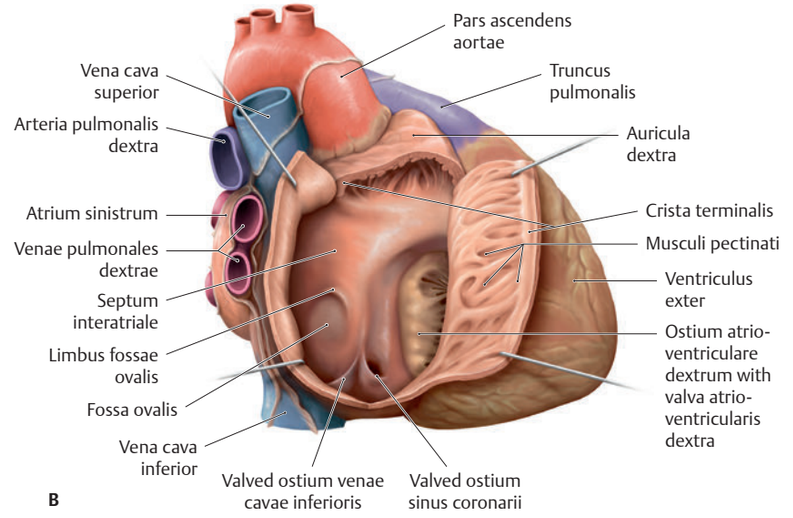


Fig. 15.50 **Surfaces of the heart**
A Facies anterior (sternocostalis). **B** Posterior surface (base). **C** Facies inferior (facies diaphragmatica).
Note the reflection of visceral pericardium serosum to become the parietal serous pericardium.





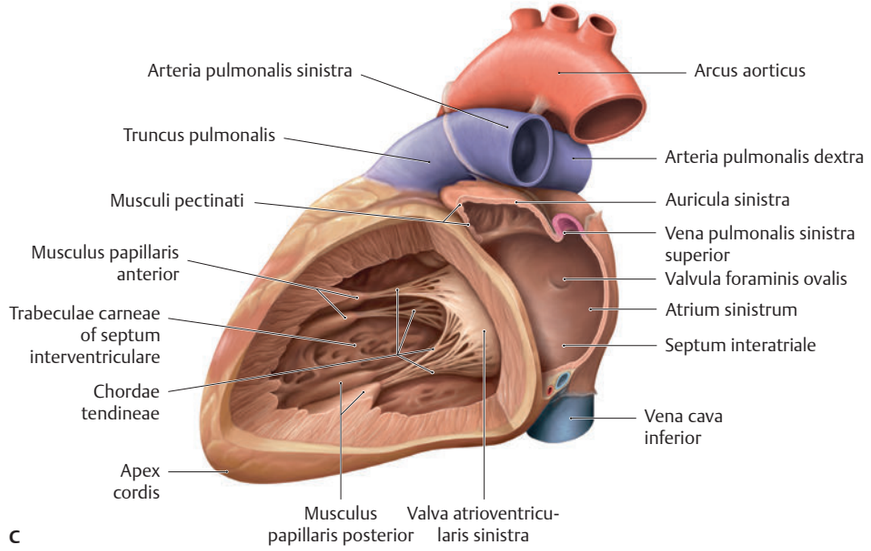
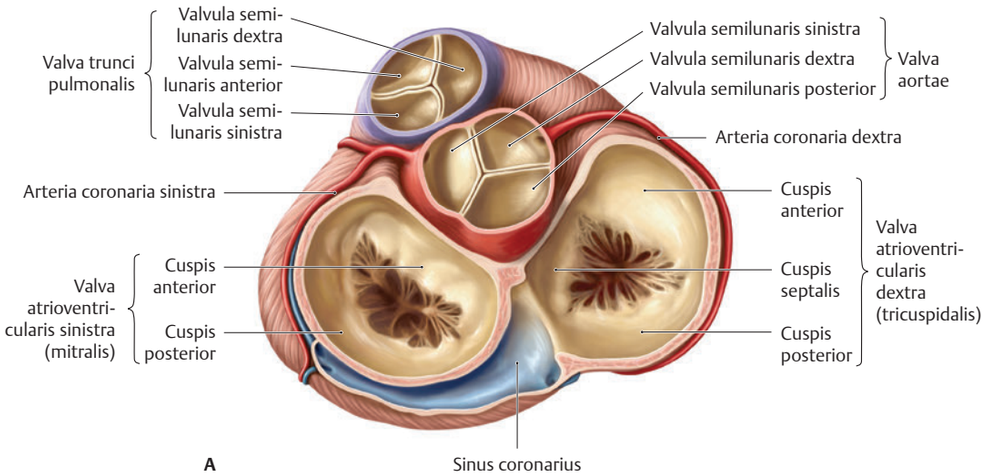


Fig. 15.51 **Chambers of the heart**
A Ventriculus dexter, anterior view. Note the crista supraventricularis, which marks the adult boundary between the embryonic ventricle and the bulbus cordis (now the conus arteriosus).
B dextrum, right lateral view.
C Atrium sinistrum and ventriculus sinister, left lateral view. Note the irregular trabeculae carneae characteristic of the ventricular wall.

Heart: Valves, Arteries, & Veins

The cardiac valves are divided into two groups: semilunar and atrioventricular. The two Valva semilunaris (valva aortae and valva trunci pulmonalis), located at the base of the two great arteries of the heart, regulate passage of blood from the ventriculi to the aorta and truncus pulmonalis. The two valvae atrioventriculares (sinistra and dextra) lie at the interface between the atria and ventriculi.



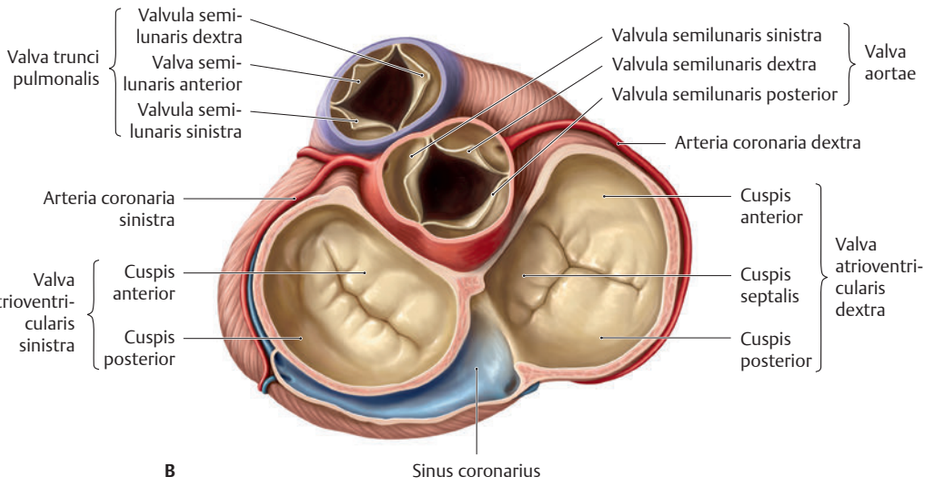
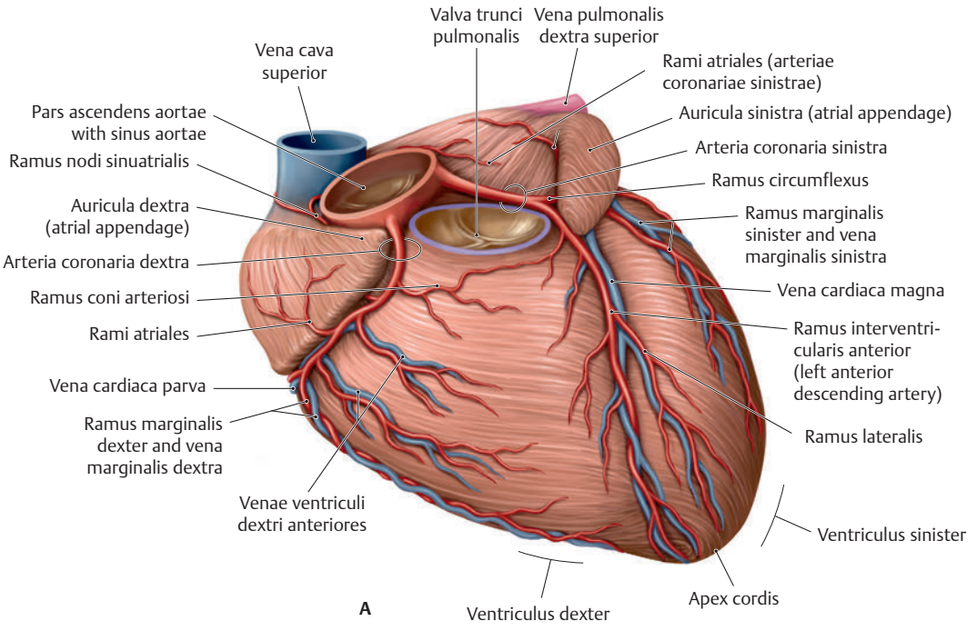


Fig. 15.52 **Cardiac valves**
Plane of cardiac valves, superior view. *Removed:* Atria and great arteries.
A Ventricular diastole (relaxation of the ventriculi). *Closed:* Valvae semilunares. *Open:* Valvae atrioventriculares.
B Ventricular systole (contraction of the ventriculi). *Closed:* Valvae atrioventriculares. *Open:* Valvae semilunares.



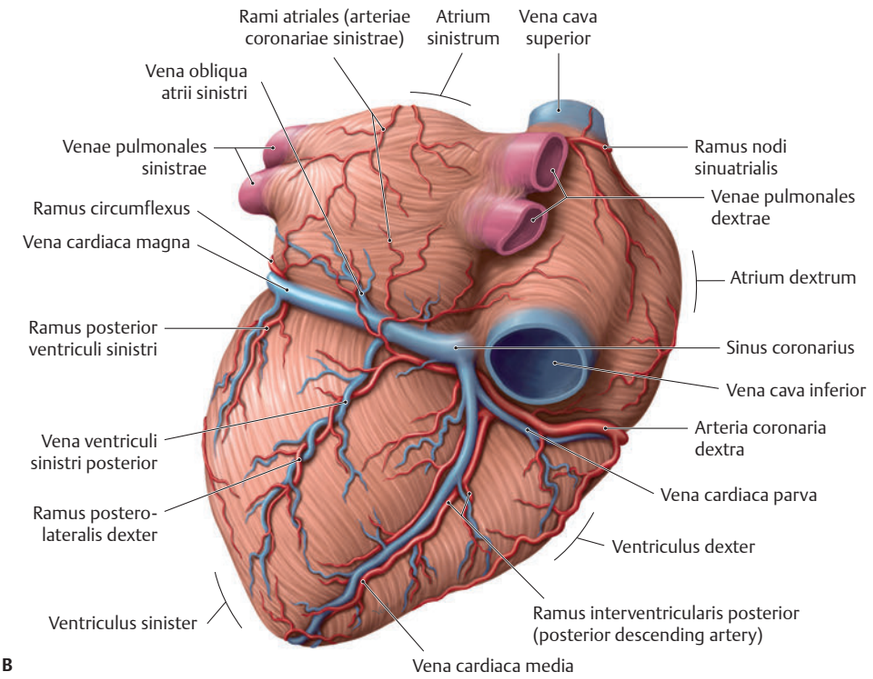


Fig. 15.53 **Arteriae coronariae and venae cordis**
A Anterior view.
B Posteroinferior view. *Note:* The right and sinistra typically anastomose posteriorly at the atrium sinistrum and ventriculus sinister.

Table 15.9 **Rami of the arteriae coronariae**

Arteria coronaria sinistra	Arteria coronaria dextra
Ramus circumflexus • Rami atriales • Ramus marginalis sinister • Ramus posterior ventriculi sinistri	Ramus nodi sinuatrialis
	Ramus coni arteriosi
	Rami atriales
	Ramus marginalis dexter
Ramus interventricularis anterior (left anterior descending) • Ramus coni arteriosi • Ramus lateralis • Rami interventriculares septales	Ramus interventricularis posterior (posterior descending) • Rami interventriculares septales
	Ramus nodi atrioventricularis
	Ramus posterolateralis dexter

Table 15.10 **Divisions of the venae cordis**

Vein	Tributaries	Drainage to
Venae cardiacae anteriores (not shown)		Atrium dextrum
Vena cardiaca magna	Vena interventricularis anterior	Sinus coronarius
	Vena marginalis sinistra	
	Vena obliqua atrii sinistri	
Vena ventriculi sinistri posterior		
Vena cardiaca media (vena interventricularis posterior)		
Vena cardiaca parva	Venae ventriculi dextri anteriores	
	Vena marginalis dextra	

Heart: Conduction & Innervation

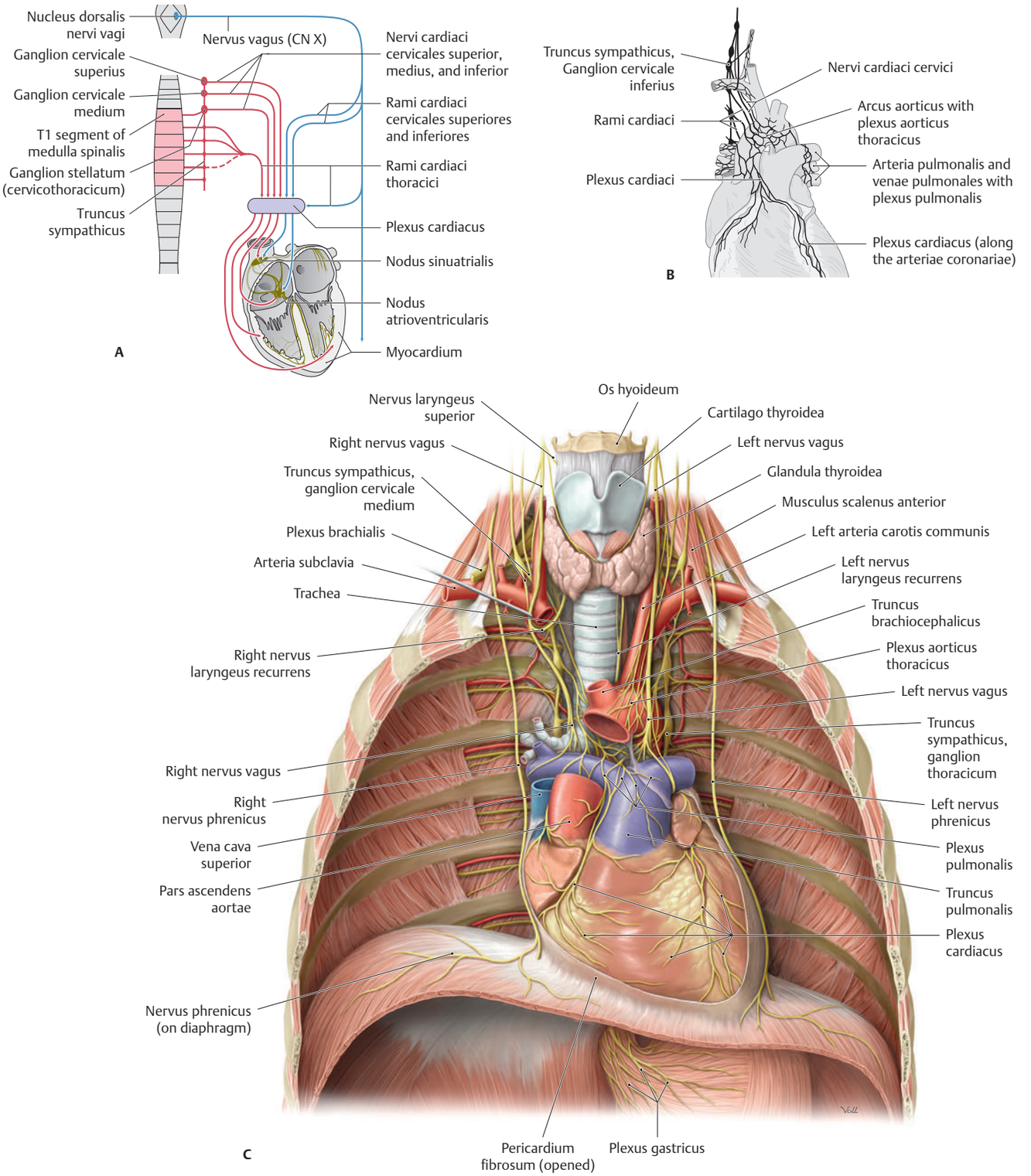


Fig. 15.54 **Autonomic innervation of the heart**
A Schematic. **Sympathetic innervation:** Preganglionic neurons from T1 to T6 segments of medulla spinalis send fibers to synapse on postganglionic neurons in the ganglia cervicalia and upper ganglia thoracica. The three nervi cardiaci cervicales and their rami cardiaci thoracici contribute to the plexus cardiacus. **Parasympathetic innervation:** Preganglionic neurons and fibers reach the heart via cardiac branches, some of which also arise in the cervical region. They synapse on postganglionic neurons near the nodus sinuatrialis and along the arteriae coronariae.
B Autonomic plexuses of the heart, right lateral view. Note the continuity between the plexus cardiacus, aortici, and pulmonalis.
C Autonomic nerves of the heart. Anterior view of opened thorax.

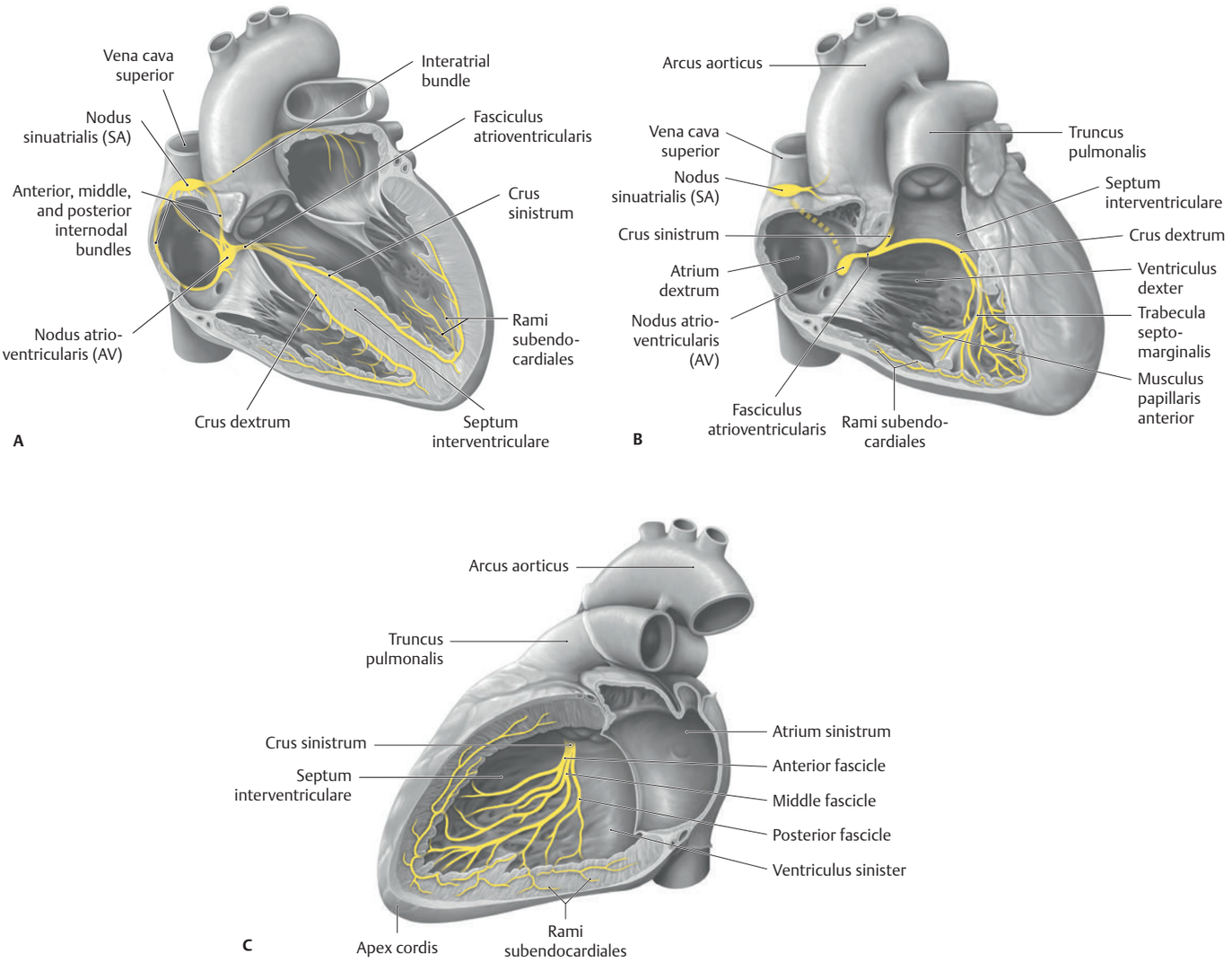


Fig. 15.55 **Systema conducens cordis**
A Anterior view. *Opened:* All four chambers.
B Right lateral view. *Opened:* Atrium dextrum and ventriculus dexter.
C Left lateral view. *Opened:* Atrium sinistrum and ventriculus sinister.
Contraction of cardiac muscle is modulated by the systema conducens cordis. This system of specialized myocardial cells (rami subendocardiales; Purkinje fibers) generates and conducts excitatory impulses in the heart. The conduction system contains two nodes, both located in the atria: the nodus sinuatrialis (SA), known as the pacemaker, and the nodus atrioventricularis (AV).

Pre- & Postnatal Circulation

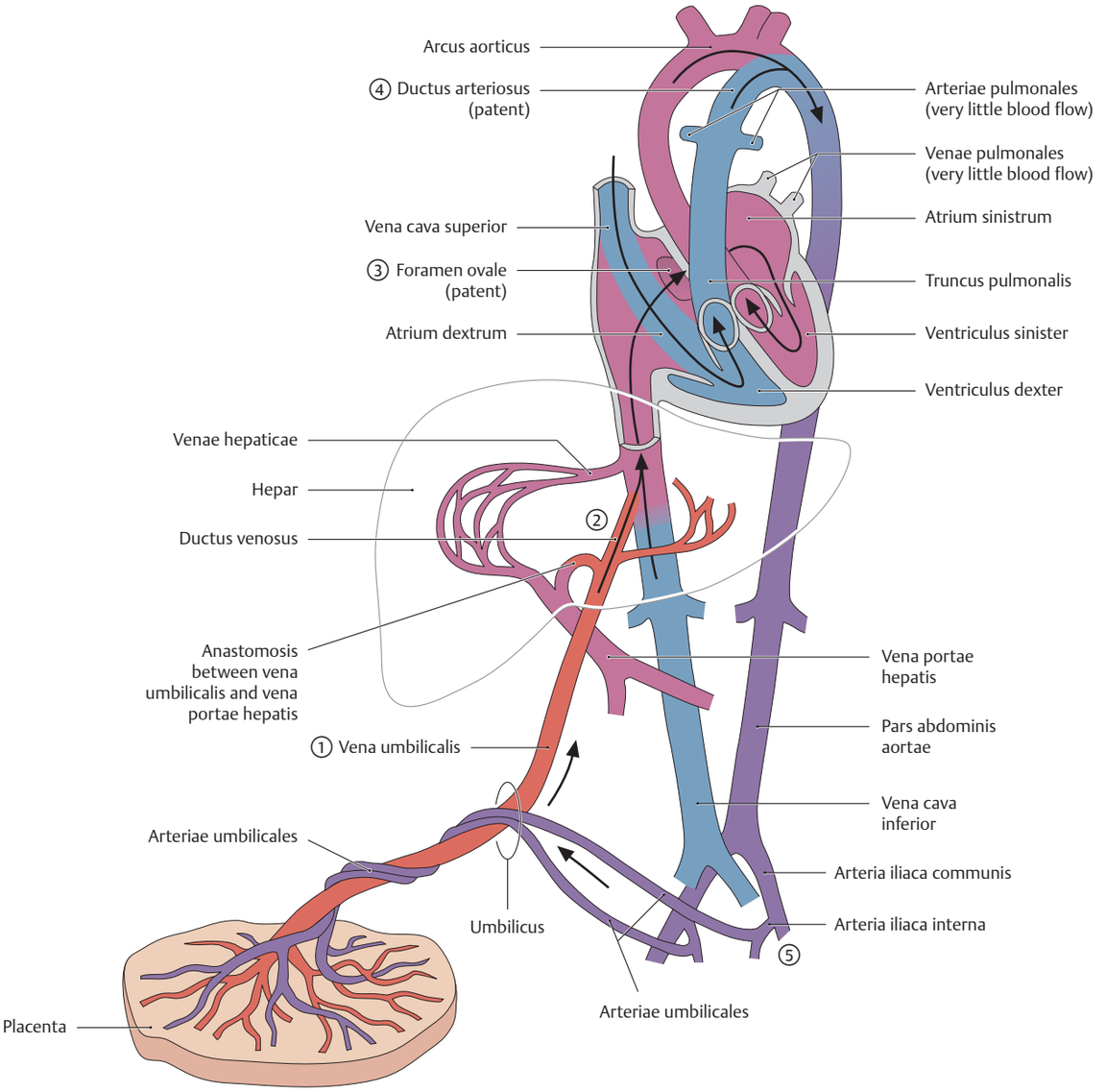


Fig. 15.56 **Prenatal circulation** (after Fritsch and Kühnel)

① Oxygenated and nutrient-rich fetal blood from the placenta passes to the fetus via the vena umbilicalis.

② Approximately half of this blood bypasses the liver (via the ductus venosus) and enters the vena cava inferior. The remainder enters the vena portae hepatis to supply the liver with nutrients and oxygen.

③ Blood entering the atrium dextrum from the vena cava inferior bypasses the ventriculus dexter (as the lungs are not yet functioning) to enter the atrium sinistrum via the foramen ovale, a right-to-left shunt.

④ Blood from the vena cava superior enters the atrium dextrum, passes to the ventriculus dexter, and moves into the truncus pulmonalis. Most of this blood enters the aorta via the ductus arteriosus, a right-to-left shunt.

⑤ The partially oxygenated blood in the aorta returns to the placenta via the paired arteriae umbilicales that arise from the arteriae iliacae internae.

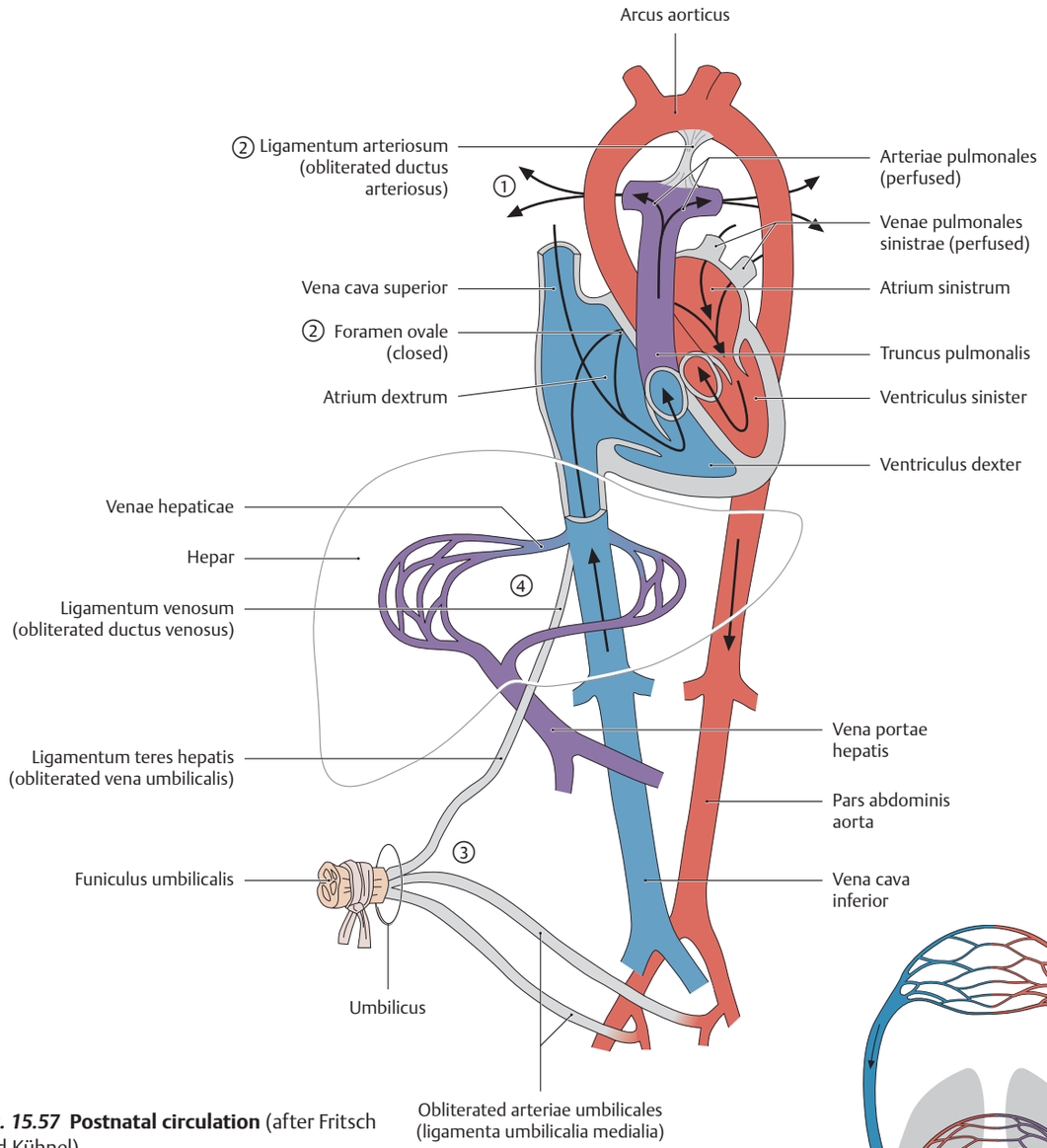


***Fig. 15.57* Postnatal circulation** (after Fritsch and Kühnel)

① As pulmonary respiration begins at birth, pulmonary blood pressure falls, causing blood from the truncus pulmonalis to enter the arteriae pulmonales.

② The foramen ovale and ductus arteriosus close, eliminating the fetal right-to-left shunts. The pulmonary and systemic circulations in the heart are now separate.

③ As the infant is separated from the placenta, the arteriae umbilicales occlude (except for the proximal portions), along with the vena umbilicalis and ductus venosus.

④ Blood to be metabolized now passes through the liver.

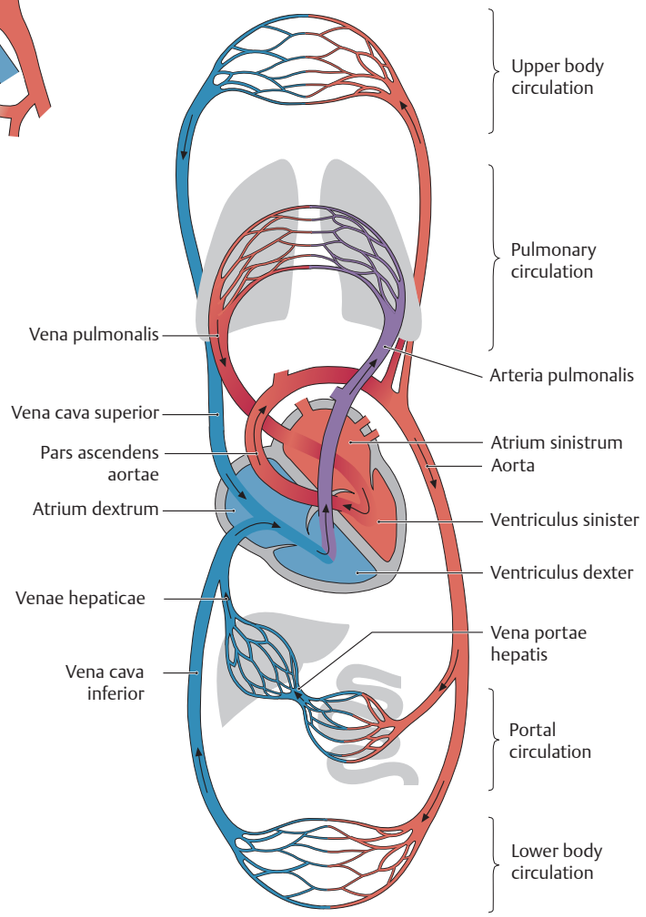


***Fig. 15.58* Circulation**
Oxygenated blood is shown in red; deoxygenated blood in blue. See **Fig 15.56** for prenatal circulation.

Oesophagus

The oesophagus is divided into three parts: pars cervicalis (C6–T1), pars thoracica (T1 to the hiatus oesophageus of the diaphragma), and abdominal (the diaphragma to the cardiac orifice of the stomach). It descends slightly to the right of the pars thoracica aortae and pierces the diaphragma slightly to the left, just below the processus xiphoideus of the sternum.

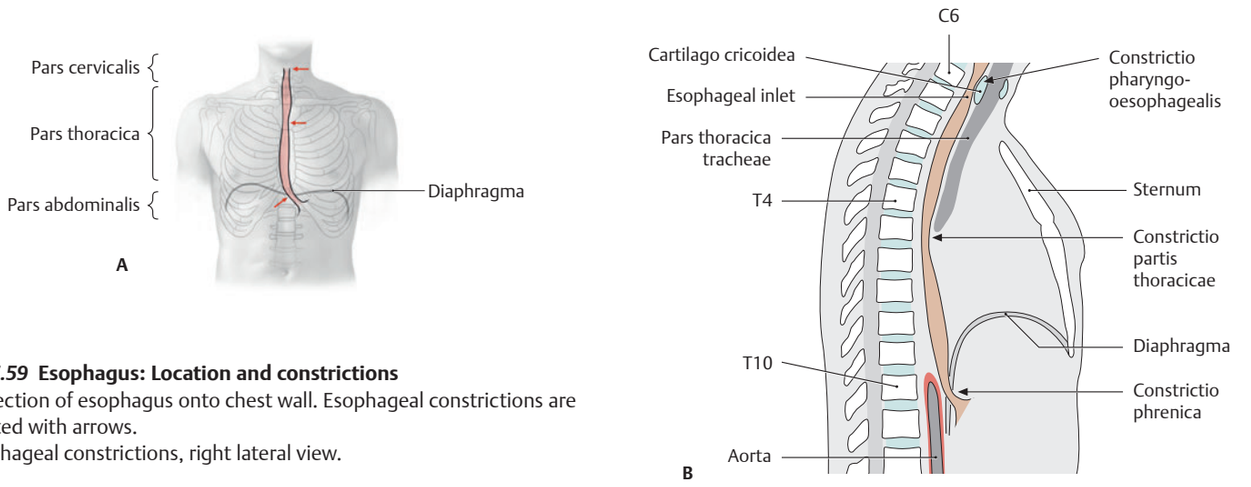


Fig. 15.59 **Esophagus: Location and constrictions**
A Projection of esophagus onto chest wall. Esophageal constrictions are indicated with arrows.
B Esophageal constrictions, right lateral view.

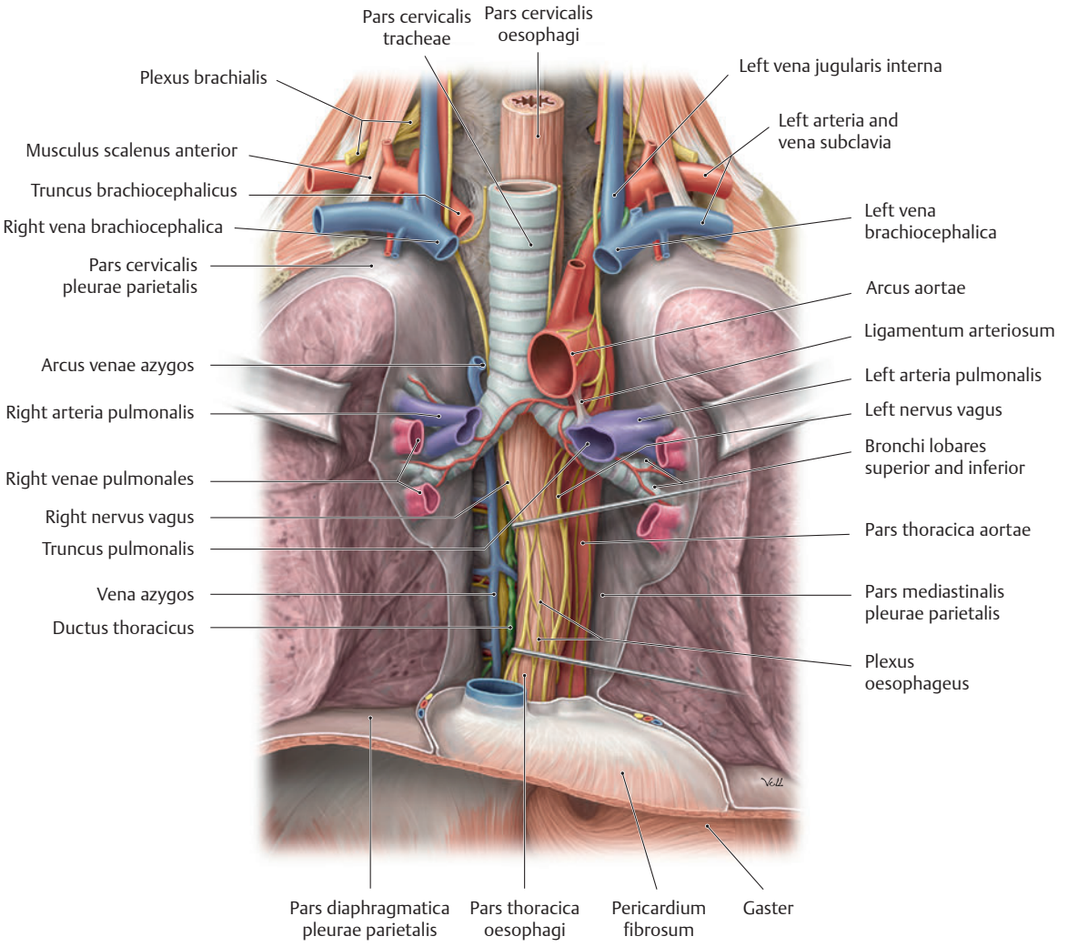


Fig. 15.60 **Oesophagus in situ**
Anterior view.

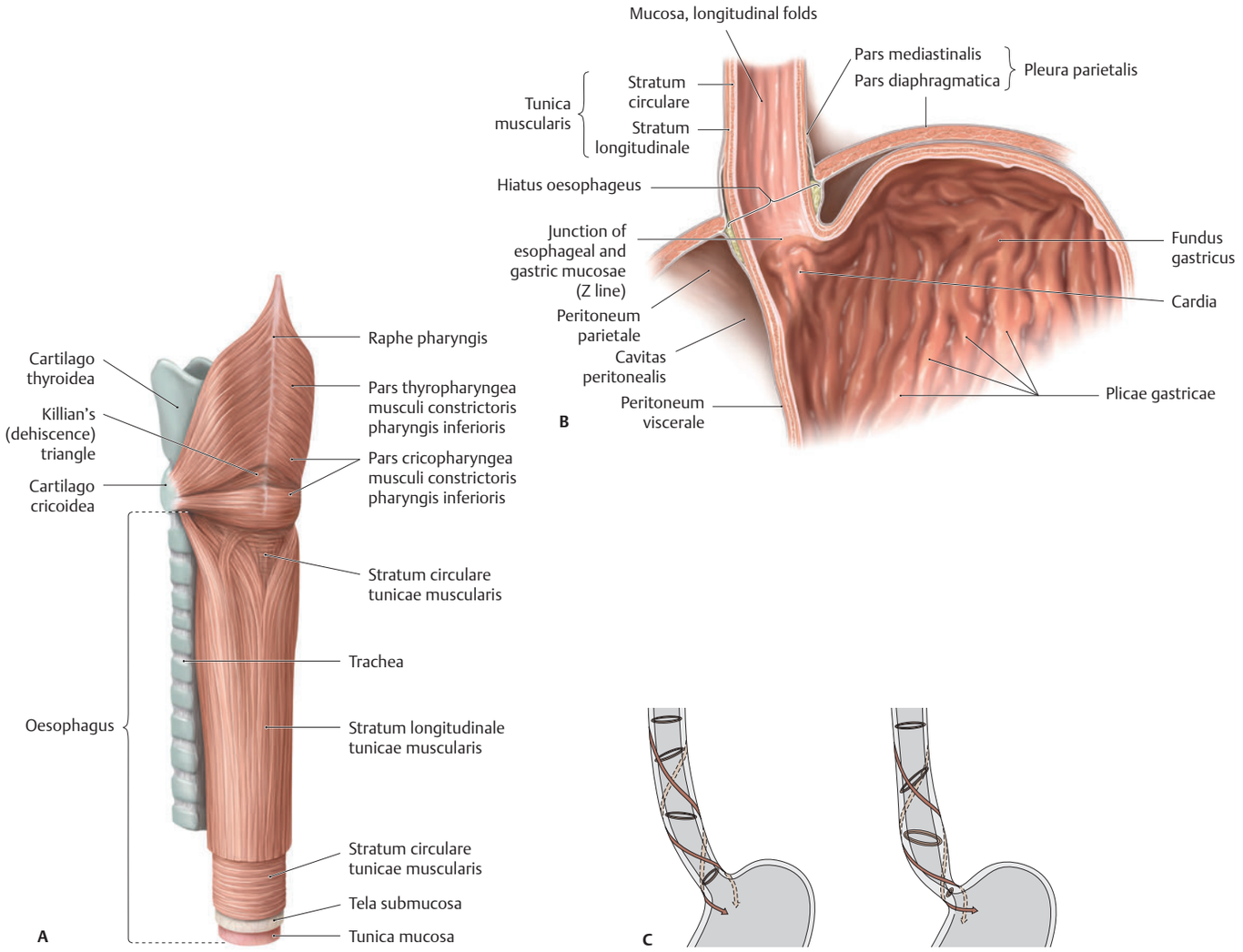


Fig. 15.61 **Structure of the oesophagus**
A Esophageal wall, oblique left posterior view.
B Esophagogastric junction, anterior view. A true sphincter is not identifiable at this junction; instead, the diaphragmatic muscle of the hiatus oesophageus functions as a sphincter. It is often referred to as the "Z line" because of its zigzag form.
C Functional architecture of esophageal muscle.

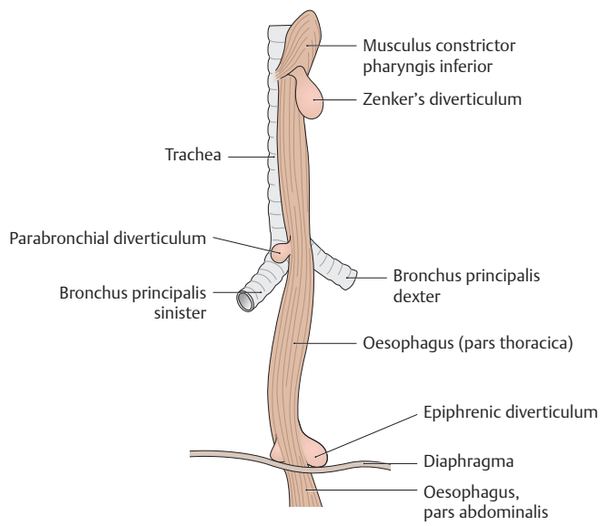


Fig. 15.62 **Esophageal diverticula**
Diverticula (abnormal outpouchings or sacs) generally develop at weak spots in the esophageal wall. There are three main types of esophageal diverticula:

- **Hypopharyngeal (pharyngo-esophageal) diverticula:** outpouchings occurring at the junction of the pharynx and the oesophagus. These include Zenker's diverticula (70% of cases).
- **"True" traction diverticula:** protrusion of all wall layers, not typically occurring at characteristic weak spots. However, they generally result from an inflammatory process (e.g., lymphangitis) and are thus common at sites where the oesophagus closely approaches the bronchi and bronchial lymph nodes (thoracic or parabronchial diverticula).
- **"False" pulsion diverticula:** herniations of the tunica mucosa and tela submucosa through weak spots in the tunica muscularis due to a rise in esophageal pressure (e.g., during normal swallowing). These include parahiatal and epiphrenic diverticula occurring above the hiatus oesophageus of the diaphragma (10% of cases).

Pleura

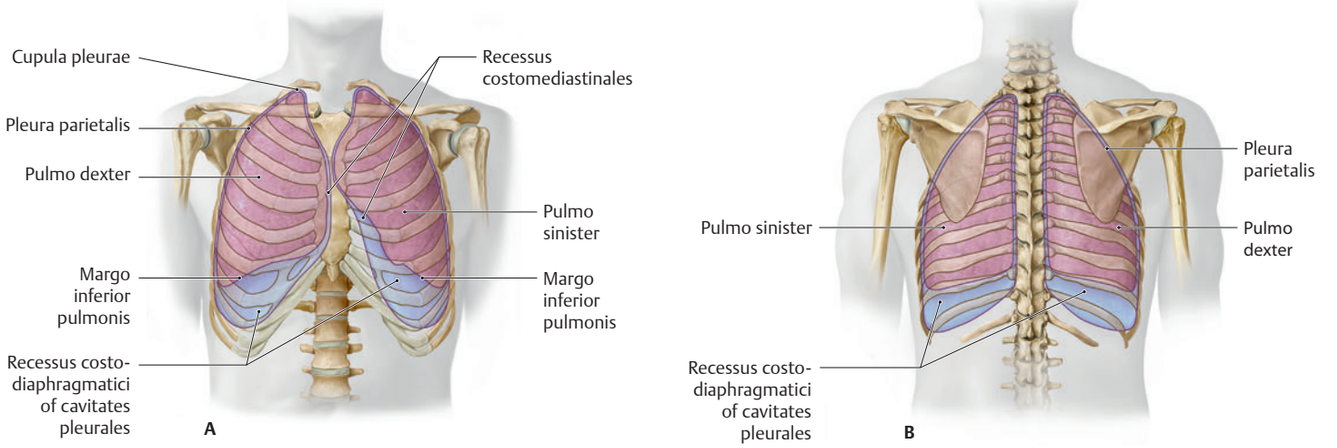


Fig. 15.63 **Vertical reference lines of the thorax**
A Anterior view. **B** Right lateral view.

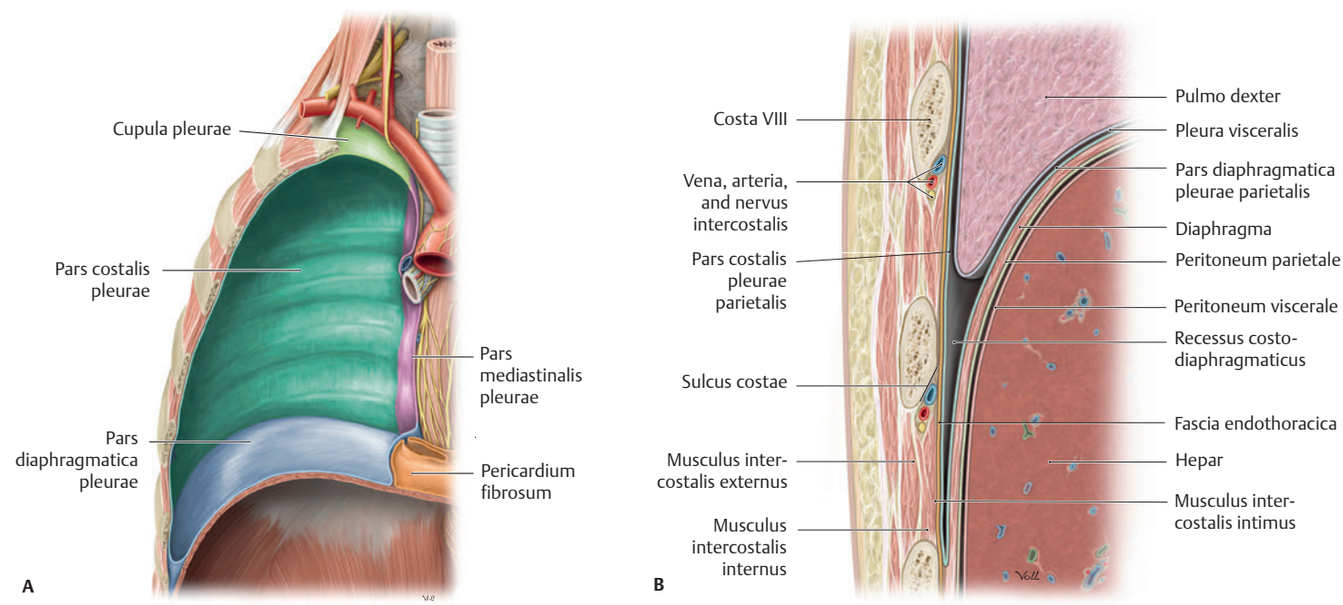


Fig. 15.64 **Pleura parietalis**
A Parts of the pleura parietalis. *Opened:* Right cavitas pleuralis, anterior view.
B Recessus costodiaphragmaticus, coronal section, anterior view. Reflection of the pars diaphragmatica pleurae onto the inner thoracic wall (becoming the pars costalis pleurae) forms the recessus costodiaphragmaticus.
The cavitas pleuralis is bounded by two serous layers. The pleura visceralis (pulmonalis) covers the lungs, and the pleura parietalis lines the inner surface of the cavitas thoracica. The four parts of the pleura parietalis (pars costalis, pars diaphragmatica, pars mediastinalis, and cupula) are continuous.

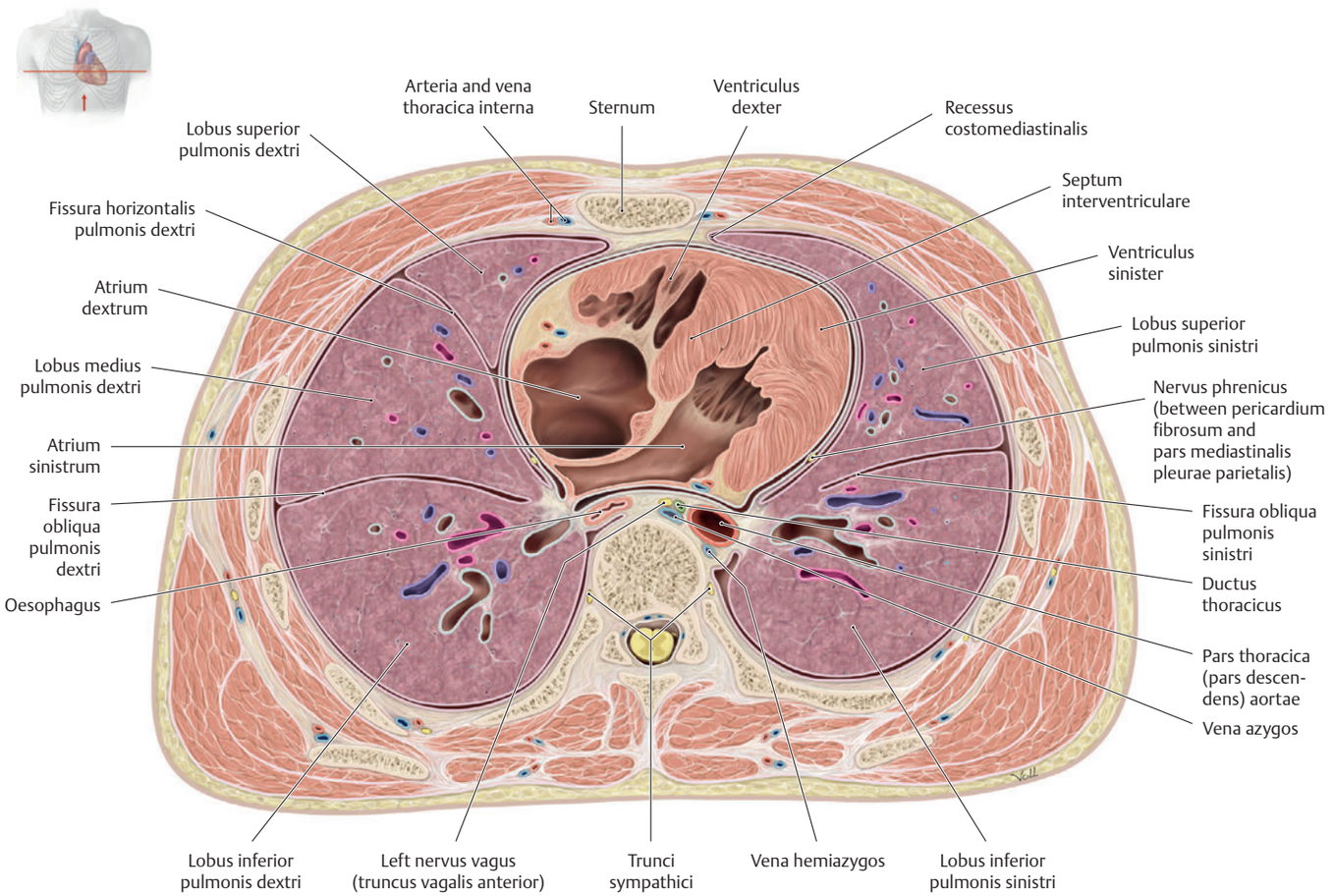


Fig. 15.65 **Thorax in transverse section**
Transverse section through T8, inferior view.

Lungs in situ

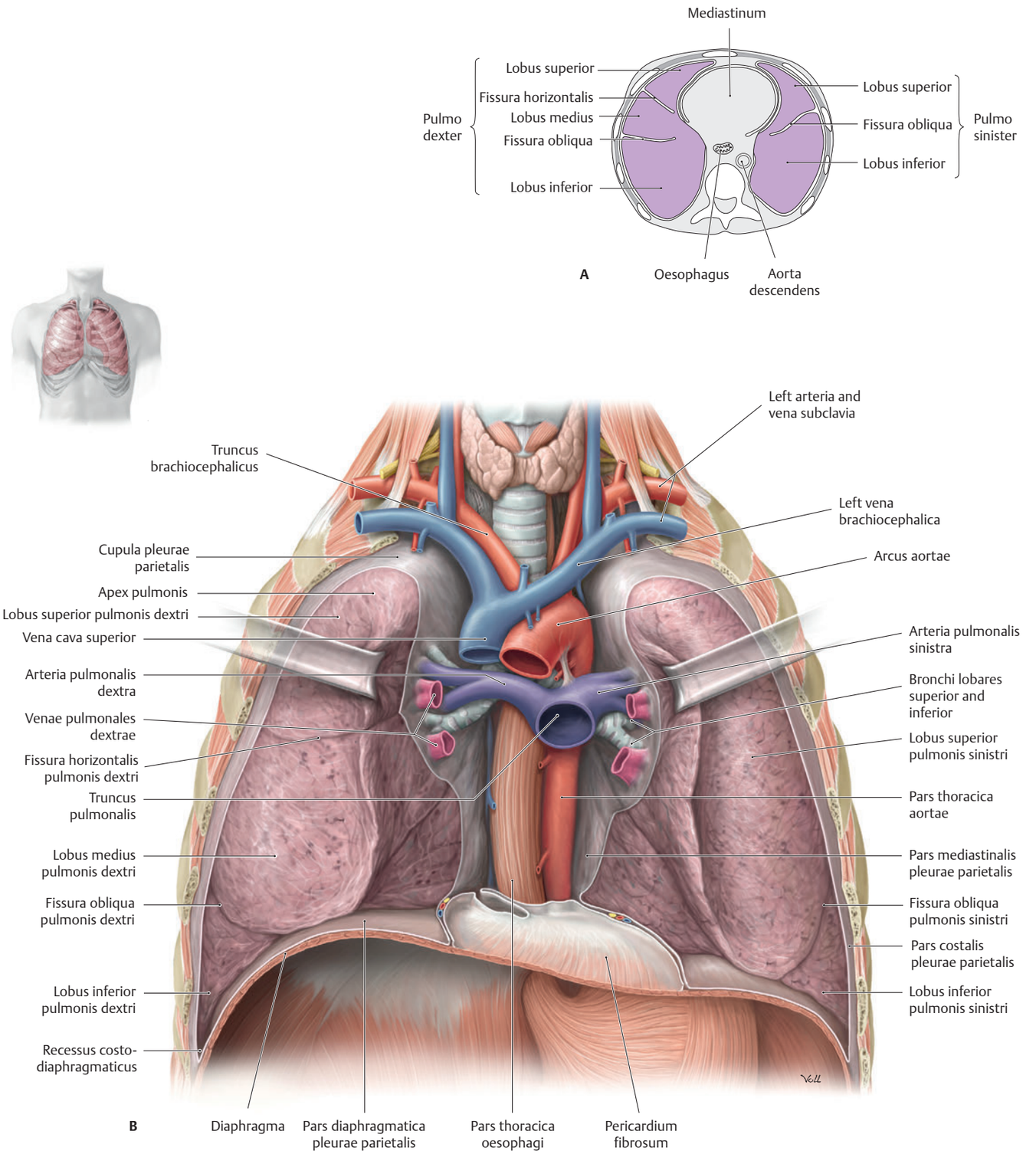


Fig. 15.66 **Lungs in situ**
The pulmones sinister and dexter occupy the full volume of the cavitas pleuralis. Note that the pulmo sinister is slightly smaller than the pulmo dexter due to the asymmetrical position of the heart.
A Topographical relations of the lungs, transverse section, inferior view.
B Anterior view with lungs retracted.

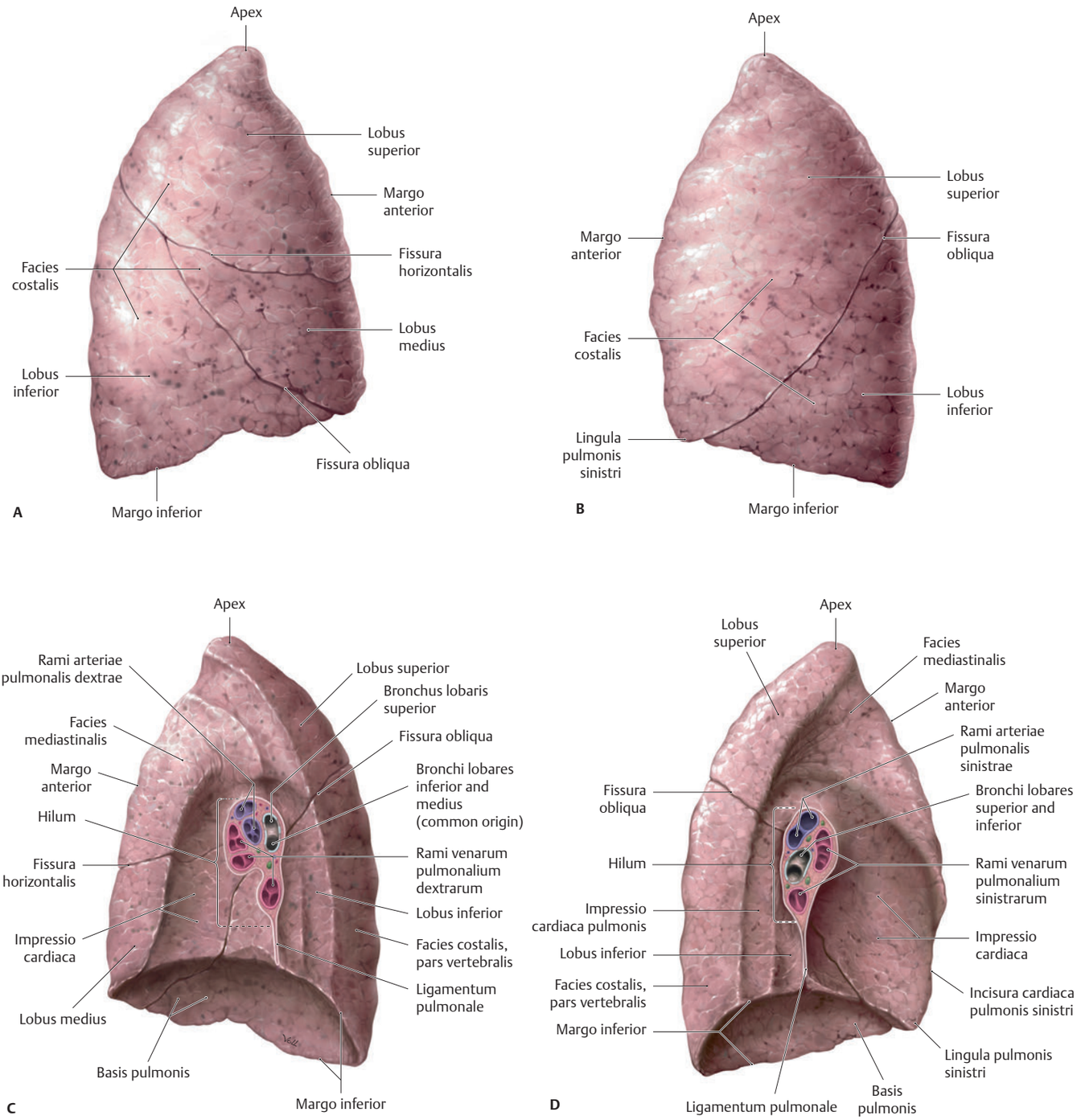


***Fig. 15.67* Gross anatomy of the lungs**
A Pulmo dexter, lateral view. **B** Pulmo sinister, lateral view. **C** Pulmo dexter, medial view. **D** Pulmo sinister, medial view. The fissurae obliqua and horizontalis divide the pulmo dexter into three lobi: superior, medius, and inferior. The fissura obliqua divides the pulmo sinister into two lobi: superior and inferior. The apex of each lung extends into the root of the neck. The hilum is the location at which the bronchi and neurovascular structures connect to the lung.

Pulmonary Arteries & Veins

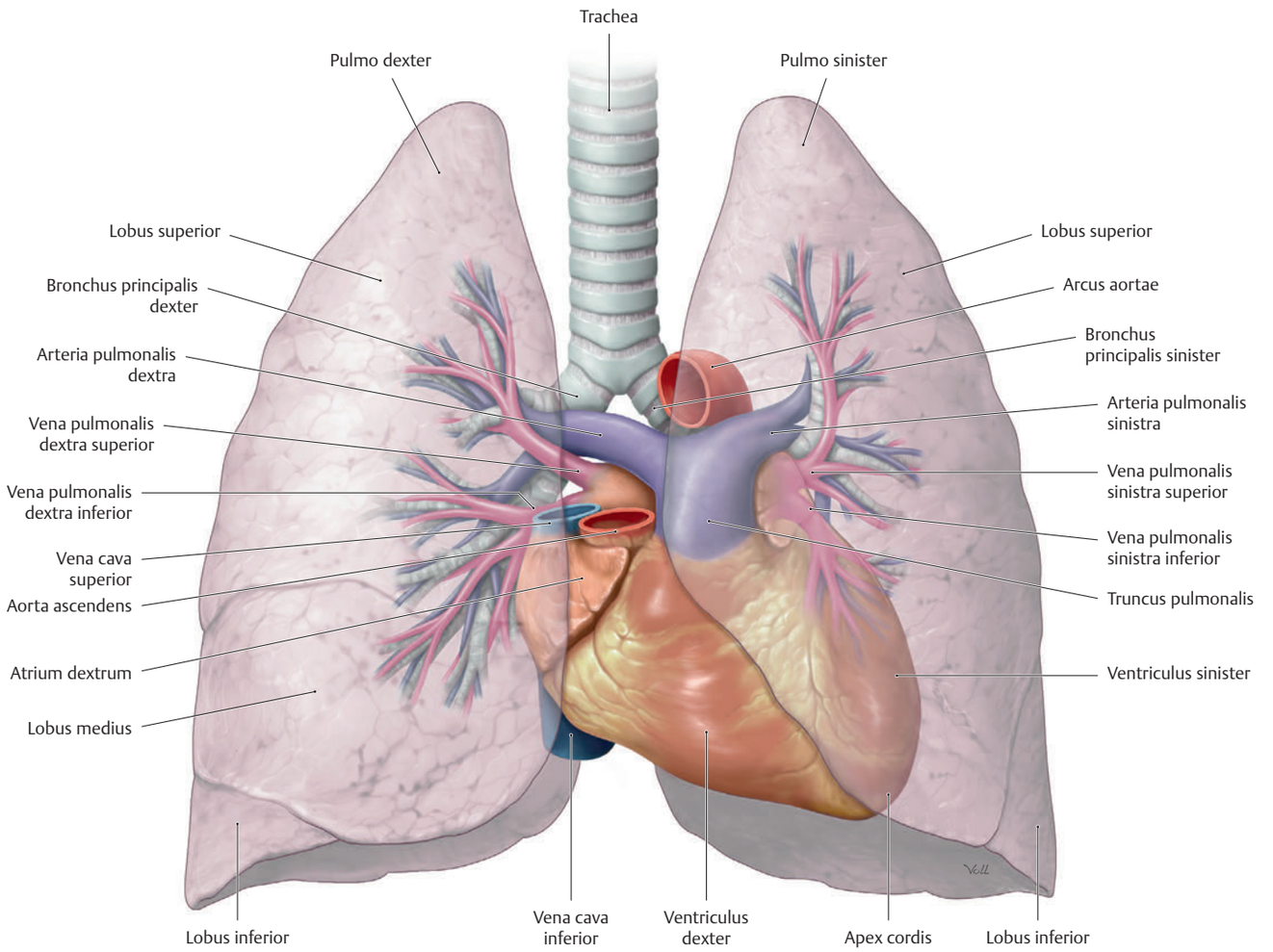


Fig. 15.68 **Arteriae and venae pulmonales**
Anterior view. The truncus pulmonalis arises from the ventriculus dexter and divides into an arteria pulmonalis sinistra and dexter. The paired venae pulmonales open into the atrium sinistrum on each side. The arteriae pulmonales accompany and follow the branching of the bronchial tree (arbor bronchialis), whereas the venae pulmonales do not, being located at the margins of the lobuli pulmonales.

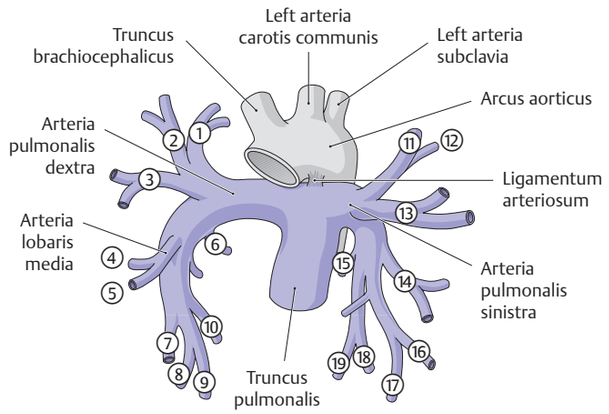


Fig. 15.69 **Arteriae pulmonales**
Schematic.

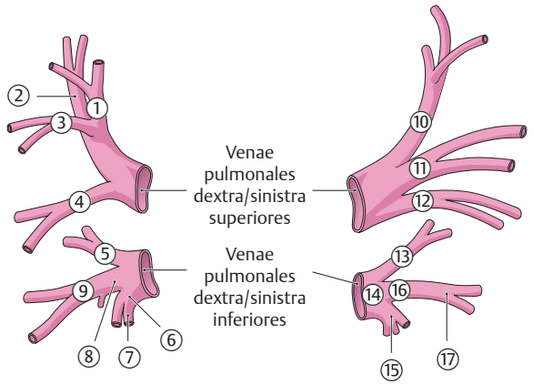


Fig. 15.70 **Venae pulmonales**
Schematic.

Table 15.11 **Arteriae pulmonales and their branches**

Arteria pulmonalis dextra		Arteria pulmonalis sinistra	
Arteriae to lobus superior			
①	Arteria segmentalis apicalis		⑪
②	Arteria segmentalis posterior		⑫
③	Arteria segmentalis anterior		⑬
Arteriae to lobus medius			
④	Arteria segmentalis lateralis	Arteria lingularis	⑭
⑤	Arteria segmentalis media		
Arteriae to lobus inferior			
⑥	Arteria segmentalis superior		⑮
⑦	Arteria segmentalis basalis anterior		⑯
⑧	Arteria segmentalis basalis lateralis		⑰
⑨	Arteria segmentalis basalis posterior		⑱
⑩	Arteria segmentalis basalis medialis		⑲

Table 15.12 **Venae pulmonales and their tributaries**

Vena pulmonalis dextra		Vena pulmonalis sinistra	
Superior venae pulmonales			
①	Vena apicalis	Vena apicoposterior	⑩
②	Vena posterior		
③	Vena anterior	Vena anterior	⑪
④	Vena lobi medii	Vena lingularis	⑫
Inferior venae pulmonales			
⑤	Vena superior		⑬
⑥	Vena basalis communis		⑭
⑦	Vena basalis inferior		⑮
⑧	Vena basalis superior		⑯
⑨	Vena basalis anterior		⑰

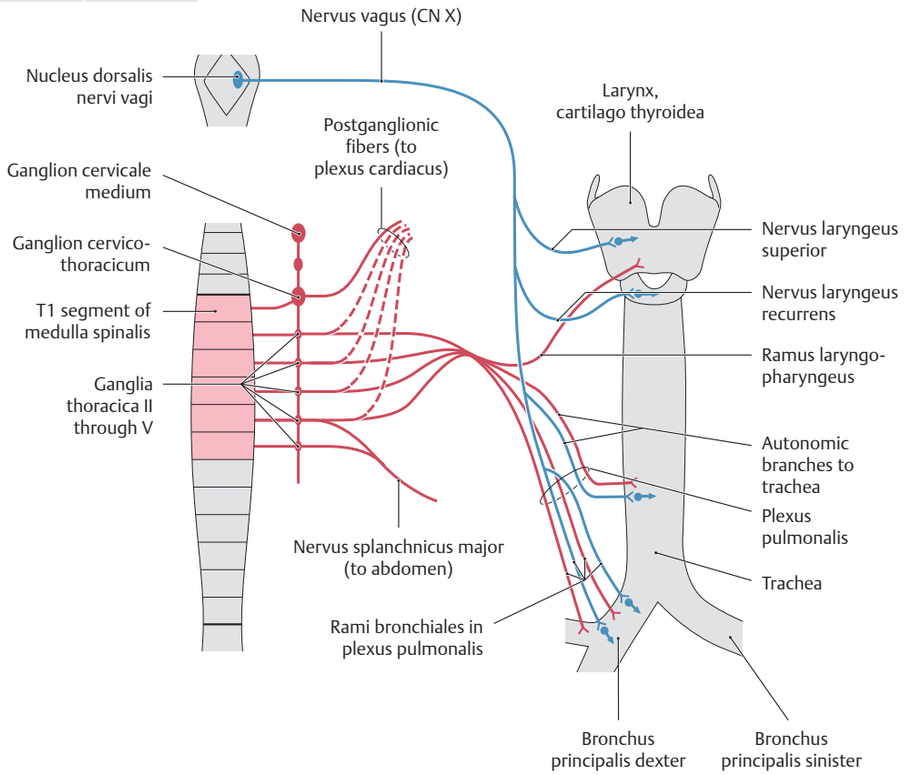


Fig. 15.71 **Autonomic innervation of the tracheobronchial tree**
Sympathetic innervation (red); parasympathetic innervation (blue).

Surface Anatomy & Muscles of the Abdominal Wall

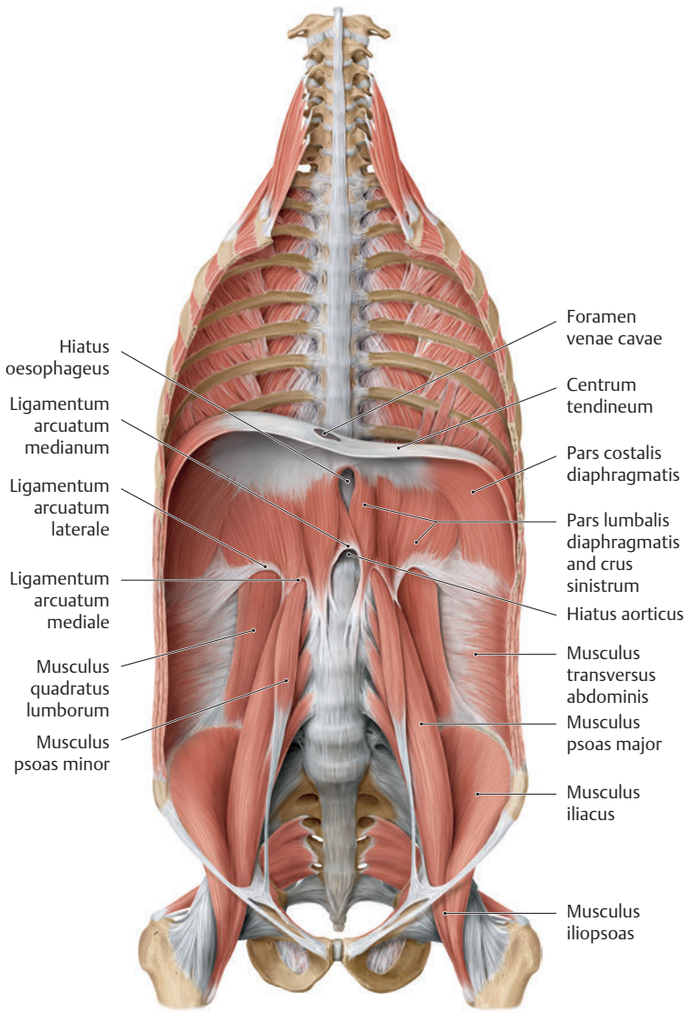


Fig. 15.72 **Muscles of the posterior abdominal wall**
Coronal section with diaphragm in intermediate position.

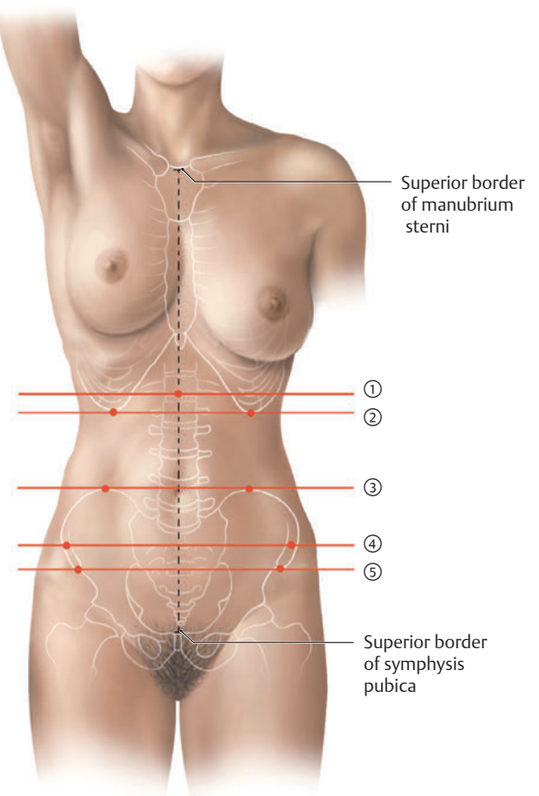


Fig. 15.73 **Plana transversalia through the abdomen**
Anterior view. See **Table 15.13**.

Table 15.13 **Transverse planes through the abdomen**

① Planum transpyloricum	Transverse plane midway between the superior borders of the symphysis pubica and the manubrium sterni
② Planum subcostalis	Plane at the lowest level of the costal margin (the inferior margin of the cartilago costalis X)
③ Planum supracrestale	Plane passing through the summits of the cristae iliacae
④ Planum transtuberculare	Plane at the level of the tubercula iliaca (the tuberculum iliacum lies ~5 cm posterolateral to the spina iliaca anterior superior)
⑤ Planum interspinale	Plane at the level of the spina iliaca anterior superior

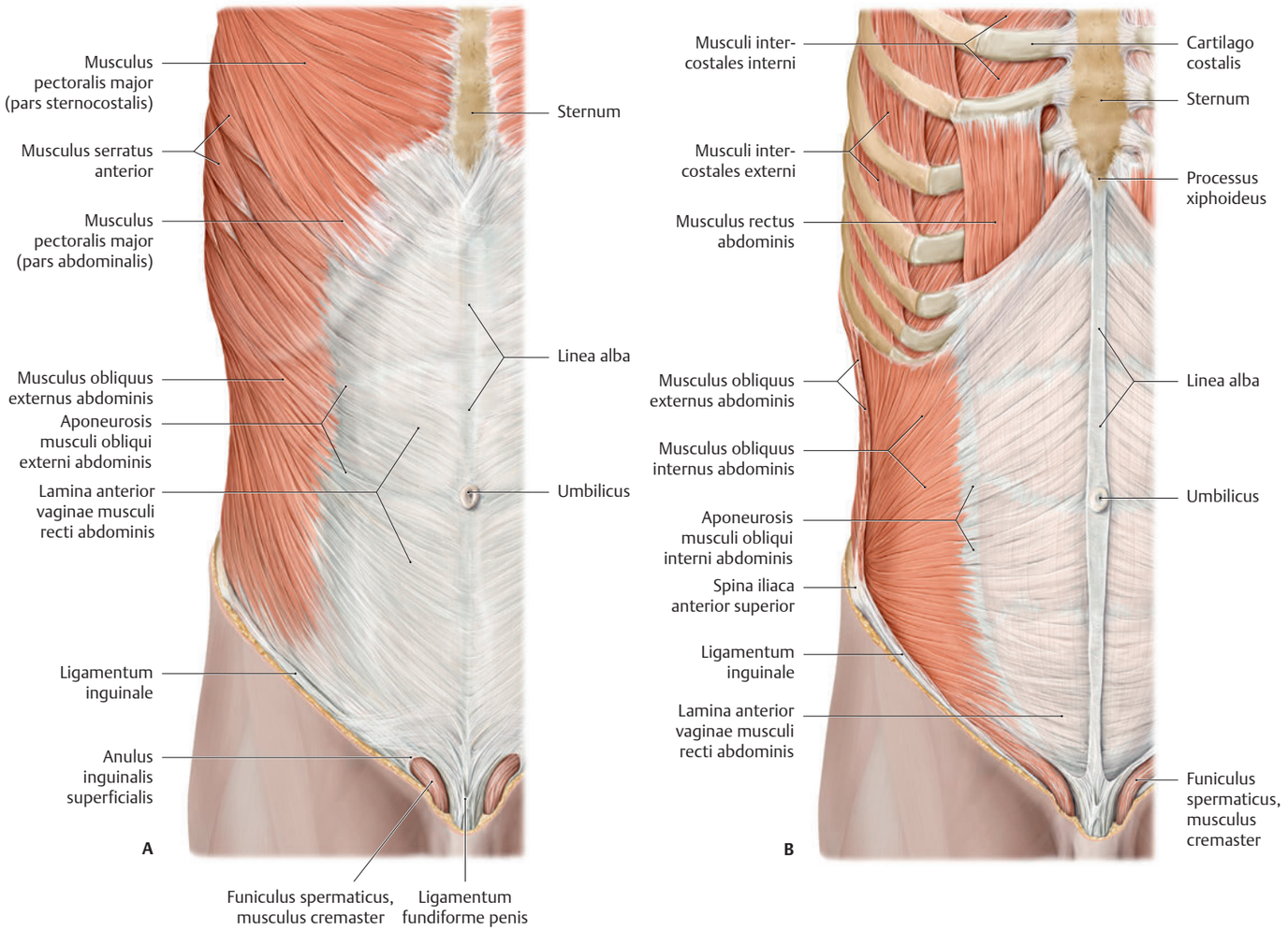


Fig. 15.74 **Muscles of the abdominal wall**
Right side, anterior view.
A Superficial abdominal wall muscles.
B *Removed:* Musculi obliquus externus abdominis, pectoralis major, and serratus anterior.

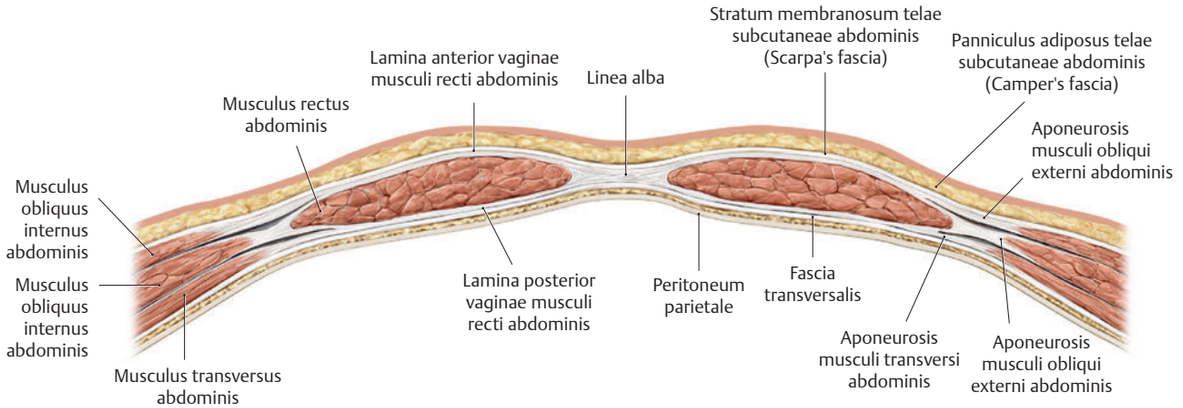


Fig. 15.75 **Anterior abdominal wall and vagina musculi recti abdominis**
Transverse section, superior to the linea arcuata.
The vagina musculi recti abdominis is created by fusion of the aponeuroses of the musculi transversus abdominis and obliqui abdominis. The inferior edge of the lamina posterior of the vagina musculi recti abdominis is called the linea arcuata.

Arteries of the Abdominal Wall & Abdomen

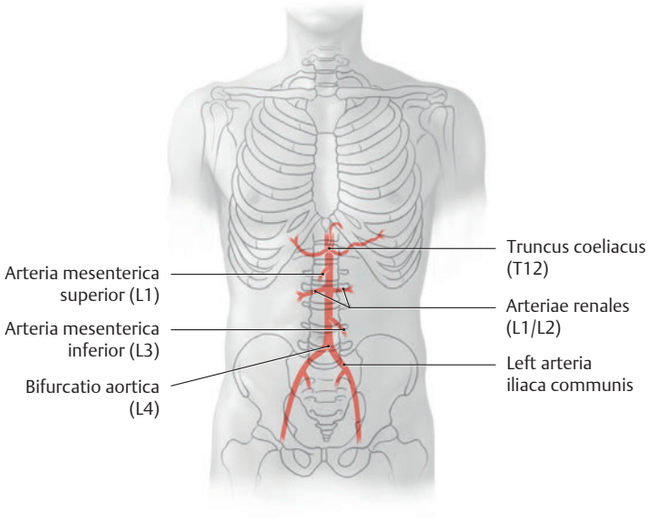


Fig. 15.76 **Pars abdominalis aortae and major branches**
Anterior view. The pars abdominalis aortae enters the abdomen at the T12 level through the hiatus aorticus of the diaphragm. Before bifurcating at L4 into its terminal branches, the arteriae iliacae communes, the aorta abdominalis gives off the arteriae renales and three major trunks that supply the organs of the alimentary canal:

Truncus coeliacus: supplies the structures of the foregut, the anterior portion of the alimentary canal. The foregut consists of the oesophagus (abdominal 1.25 cm), stomach (gaster), duodenum (proximal half), liver (hepar), gallbladder (vesica biliaris), and pancreas (superior portion).

Arteria mesenterica superior: supplies the structures of the midgut:

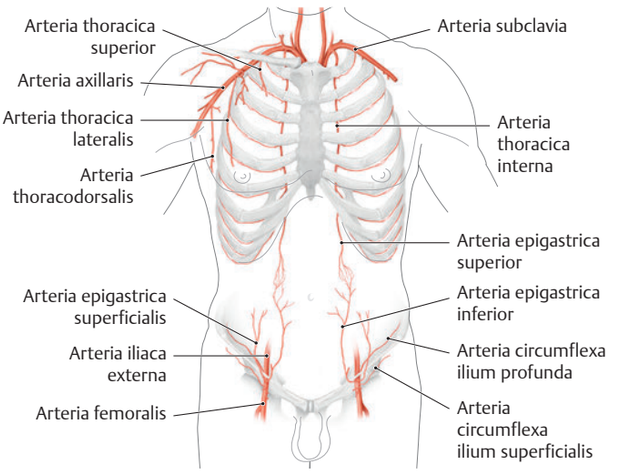


Fig. 15.77 **Arteries of the abdominal wall**
The arteriae epigastricae superior and inferior form a potential anastomosis, or bypass for blood, from the arteriae subclavia and femoralis. This effectively allows blood to bypass the aorta abdominalis.

the duodenum (distal half), jejunum and ileum, caecum and appendix, colon ascendens, flexura coli dextra, and the proximal one half of the colon transversum.

Arteria mesenterica inferior: supplies the structures of the hindgut: the colon transversum (distal half), flexura coli sinistra, cola descendens and sigmoideum, rectum, and canalis analis (upper part).

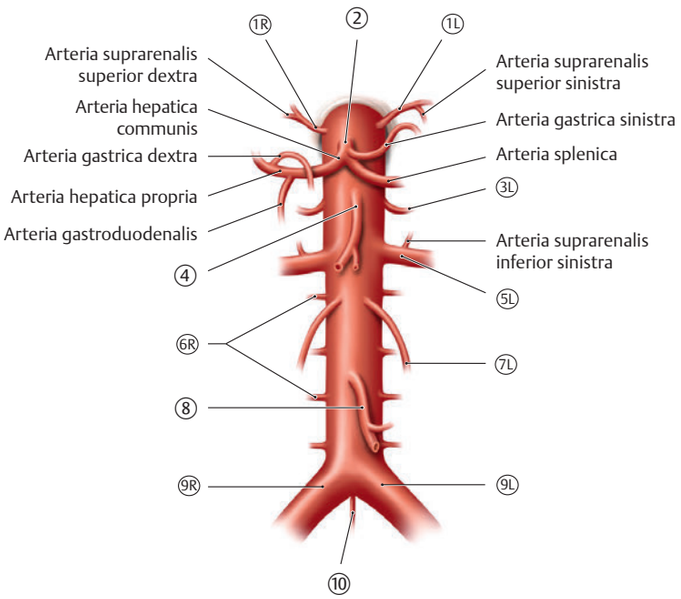


Fig. 15.78 **Branches of the aorta abdominalis**
Anterior view. See **Table 15.14**.

Table 15.14 **Branches of the aorta abdominalis**

The pars abdominalis aortae gives rise to three major unpaired trunks (bold) and the unpaired arteria sacralis mediana, as well as six paired branches.

Branch from aorta abdominalis			Branches	
1R	1L	Arteriae phrenicae inferiores (paired)	Arteriae suprarenales superiores	
2		**Truncus coeliacus**	Arteria gastrica sinistra	
			Arteria splenica	
			Arteria hepatica communis	Arteria hepatica propria
				Arteria gastrica dextra
				Arteria gastroduodenalis
3R	3L	Arteriae suprarenales mediae (paired)		
4		**Arteria mesenterica superior**		
5R	5L	Arteriae renales (paired)	Arteriae suprarenales inferiores	
6R	6L	Arteriae lumbales (1st through 4th, paired)		
7R	7L	Arteriae testiculares/ovaricae (paired)		
8		**Arteria mesenterica inferior**		
9R	9L	Arteriae iliacae communes (paired)	Arteria iliaca externa	
			Arteria iliaca interna	
10		Arteria sacralis mediana		

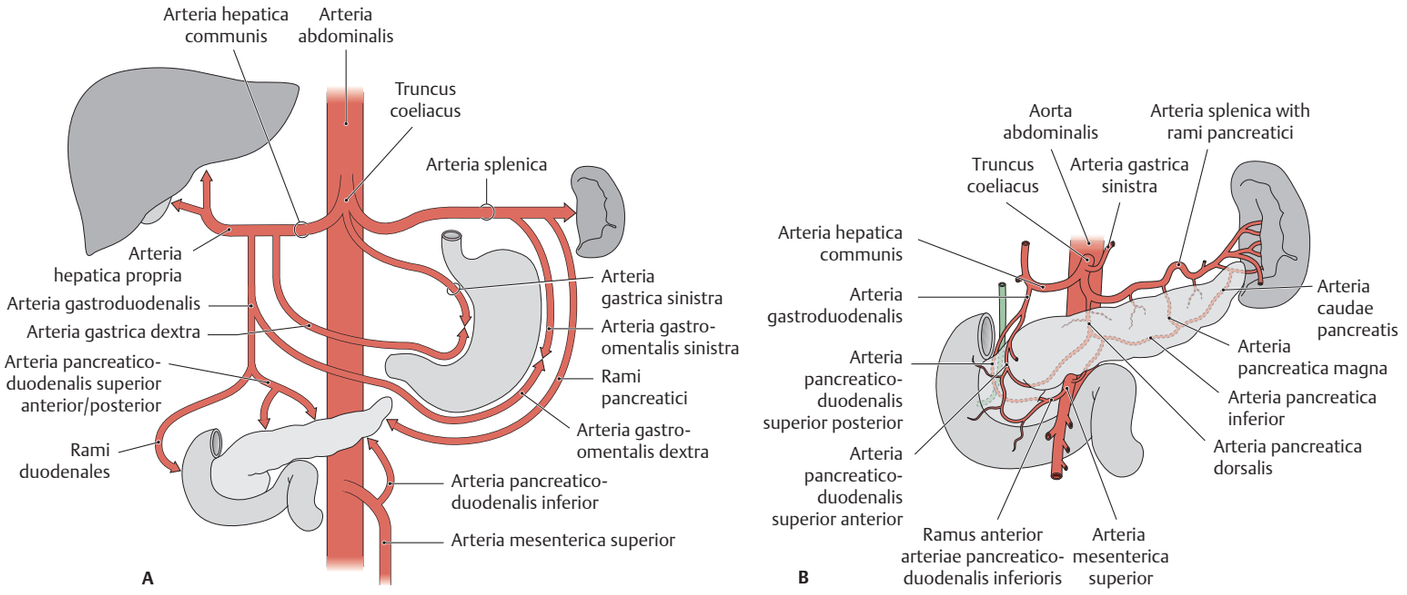
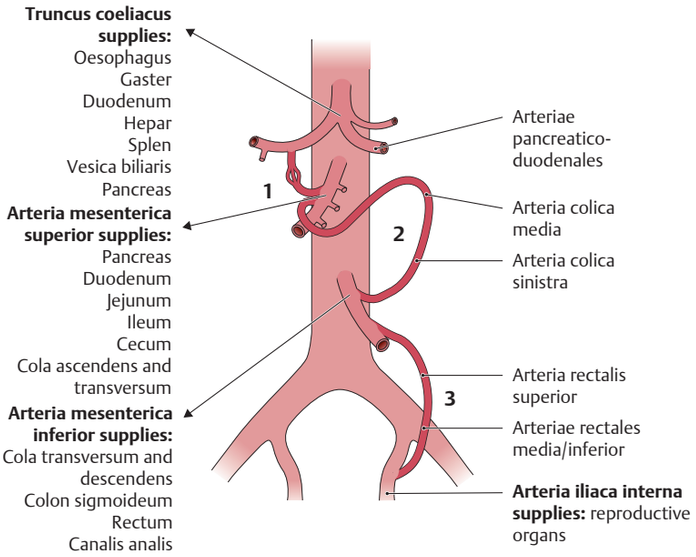


Fig. 15.79 **Truncus coeliacus**
A Truncus coeliacus distribution. **B** Arterial supply to the pancreas.

Fig. 15.80 **Abdominal arterial anastomoses**
The three major anastomoses provide overlap in the arterial supply to abdominal areas to ensure adequate blood flow. These are between
① the truncus coeliacus and the arteria mesenterica superior via the arteriae pancreaticoduodenales,
② the arteriae mesentericae superior and inferior via the arteriae colicae media and sinistra, and
③ the arteriae mesenterica inferior and the iliaca interna via the arteriae rectales superior and media or inferior.



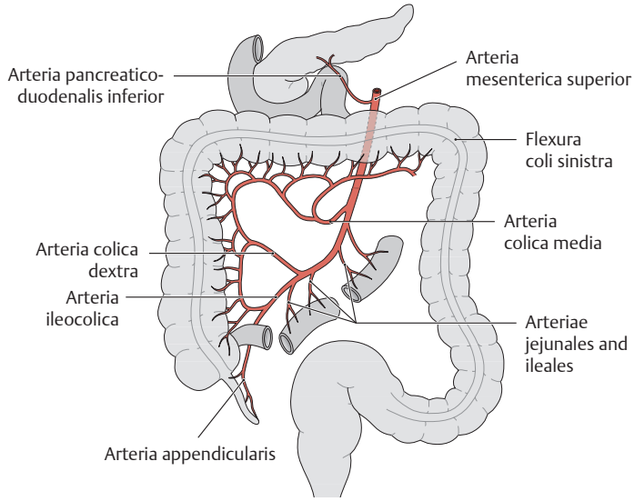


Fig. 15.81 **Arteria mesenterica superior**

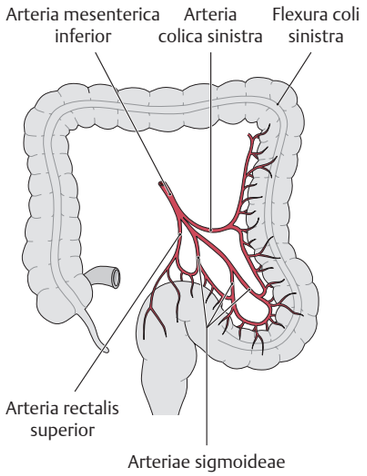


Fig. 15.82 **Arteria mesenterica inferior**

Divisions of the Cavitas Abdominis & Pelvis

Organs in the cavitas abdominis et pelvis are classified by the presence of surrounding peritoneum (the serous membrane lining the cavity) and a mesenterium (a double layer of peritoneum that connects the organ to the abdominal wall) (see **Table 15.15**).

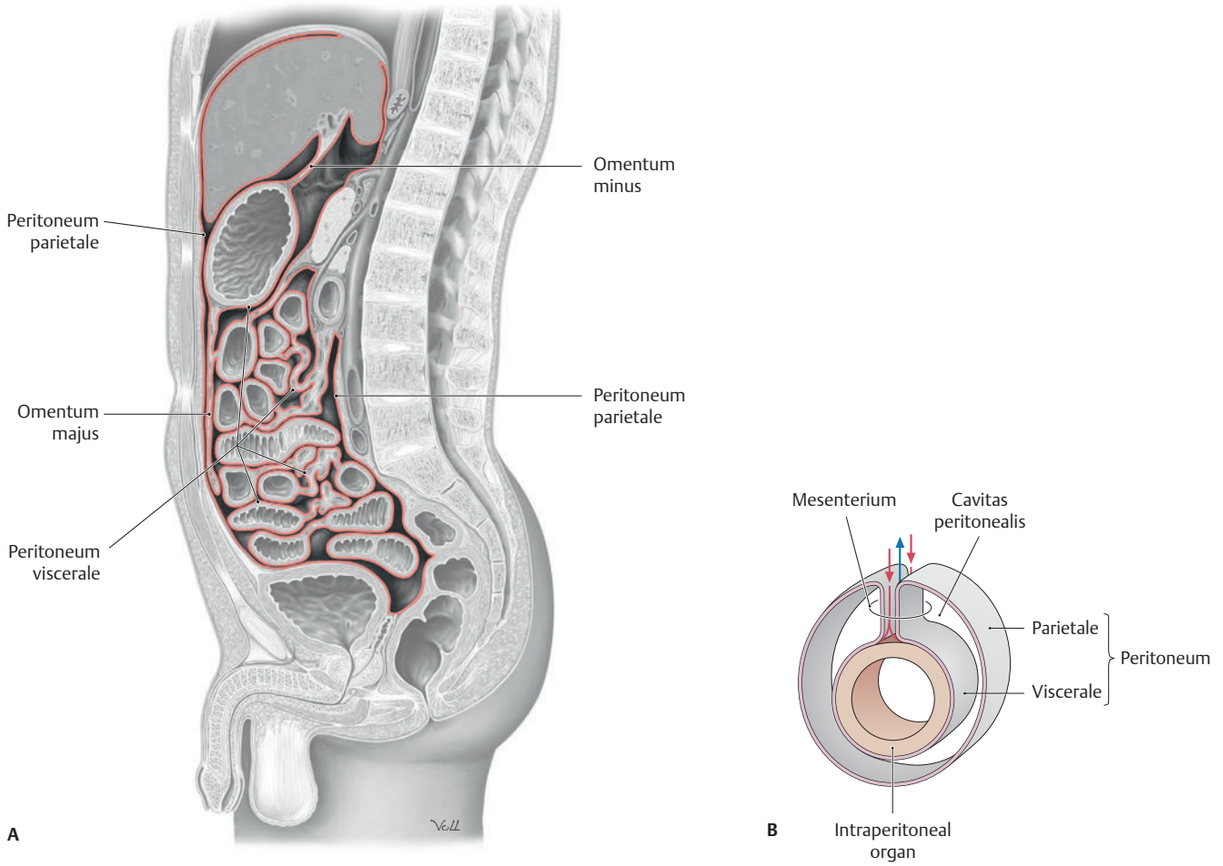


Fig. 15.83 **Cavitas peritonealis**
A Midsagittal section through the male cavitas abdominis et pelvis, viewed from the left. The peritoneum is shown in red.
B An intraperitoneal organ, showing the mesenterium and surrounding peritoneum. Arrows indicate location of blood vessels in the mesenterium.

Table 15.15 **Organs of the cavitas abdominis et pelvis classified by their relationship to the peritoneum**

Location		Organs		
Intraperitoneal organs: These organs have a mesenterium and are completely covered by the peritoneum.				
Abdominal peritoneal		• Gaster • Intestinum tenue (jejunum, ileum, some of the pars superior of the duodenum) • Splen • Hepar	• Vesica biliaris • Caecum with appendix vermiformis • Intestinum crassum (cola transversum and sigmoideum)	
Pelvic peritoneal		• Uterus (fundus and corpus)	• Ovaria	• Tubae uterinae
Extraperitoneal organs: These organs either have no mesenterium or lost it during development.				
Retroperitoneal	Primarily	• Rena and ureteres	• Glandulae suprarenales	• Cervix uteri
	Secondarily	• Duodenum (partes descendens, horizontalis, and ascendens) • Pancreas	• Cola ascendens and descendens • Rectum (upper 2/3)	
Infraperitoneal/subperitoneal		• Vesia urinaria • Distal ureters • Prostata	• Glandula vesiculosa • Cervix uteri	• Vagina • Rectum (lower 1/3)

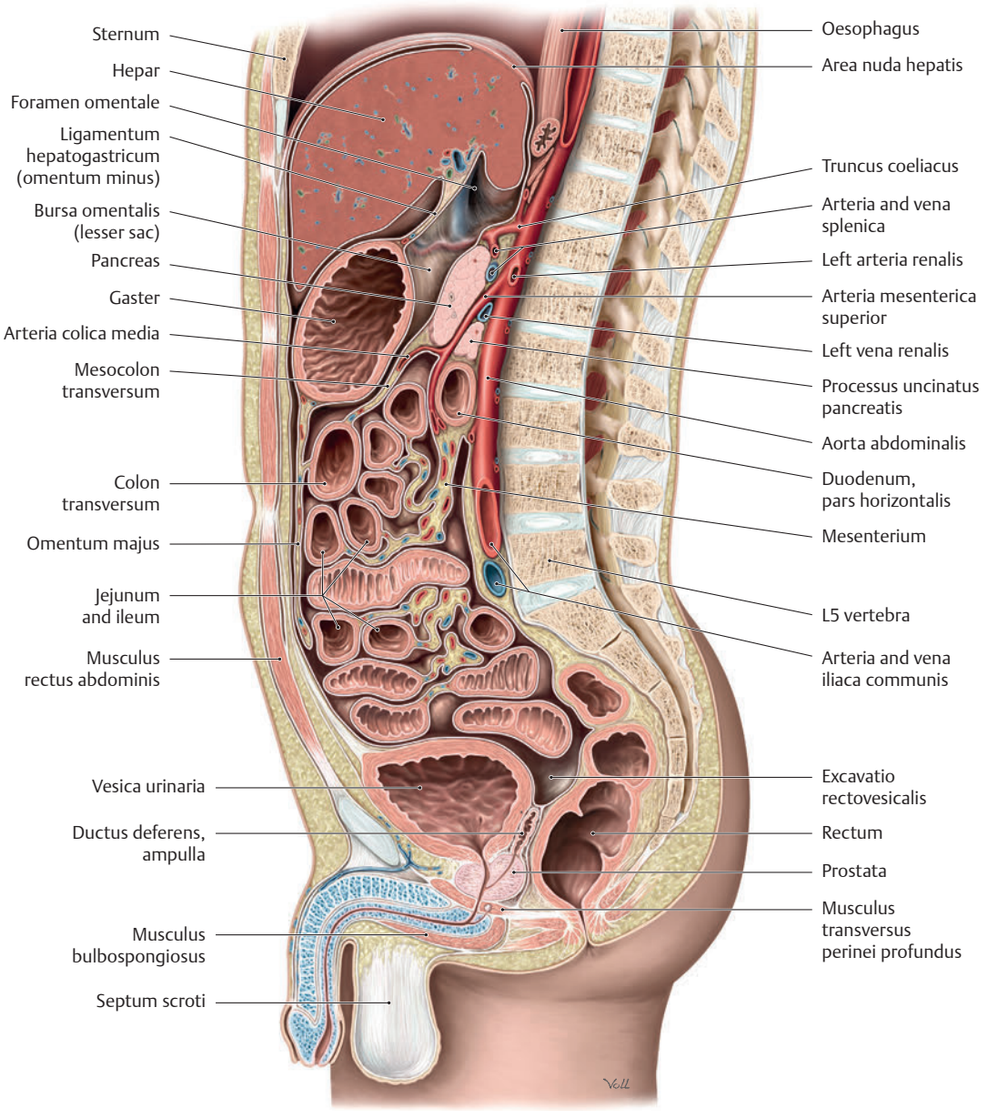


Fig. 15.84 **Peritoneal relationships of the abdominopelvic organs**
Midsagittal section through the male cavitas abdominis et pelvis, viewed from the left.

Cavitas Peritonealis & Mesenteria (I)

The cavitas peritonealis is divided into the large greater sac and small bursa omentalis (lesser sac). The omentum majus is an apron-like fold of peritoneum suspended from the curvatura major gastri and covering the anterior surface of the colon transversum. The attachment of the mesocolon transversum on the anterior surface of the pars descendens duodeni and the pancreas divides the cavitas peritonealis into a supracolic compartment (hepar, vesica biliaris, and gaster) and an infracolic compartment (intestines).

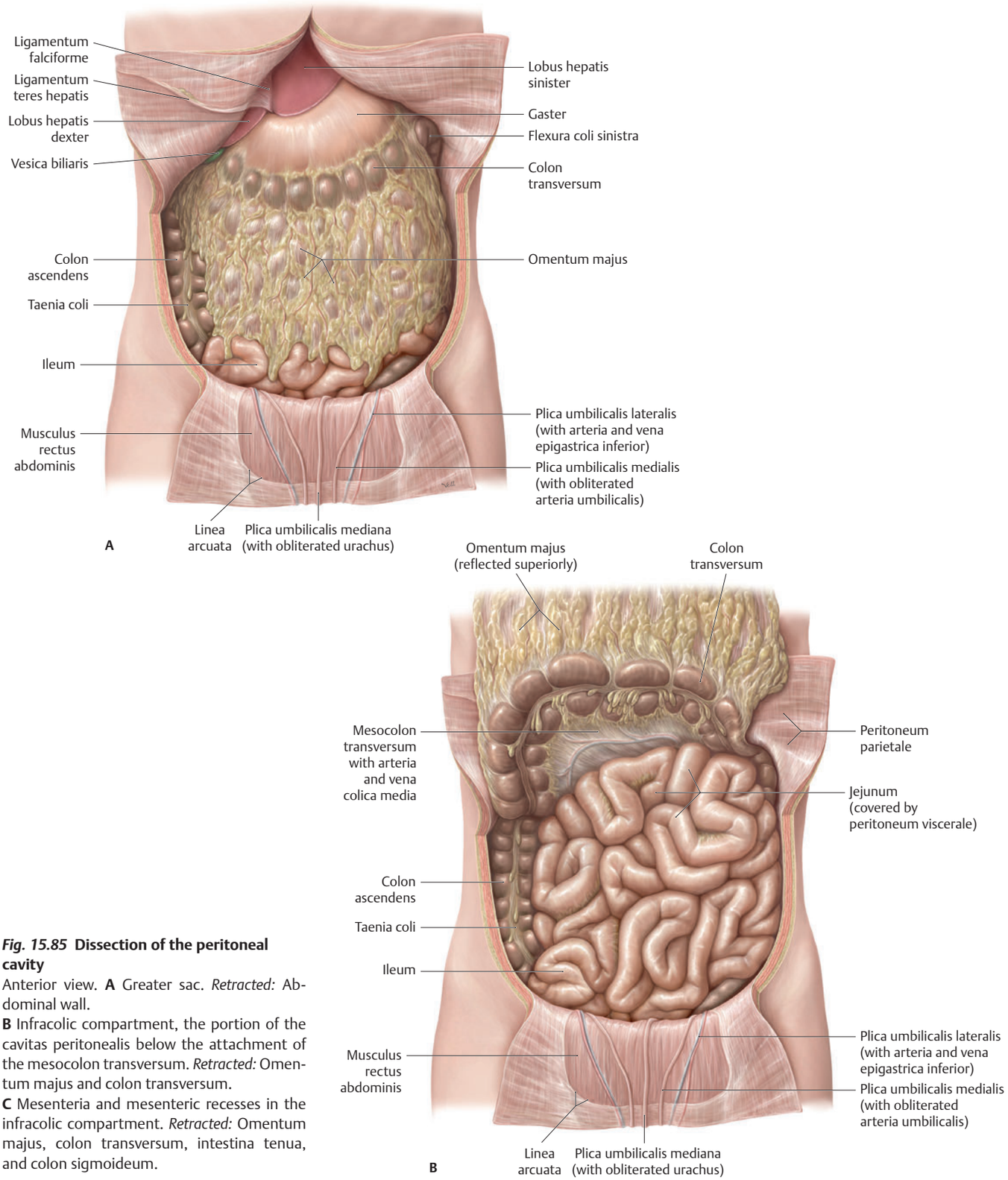
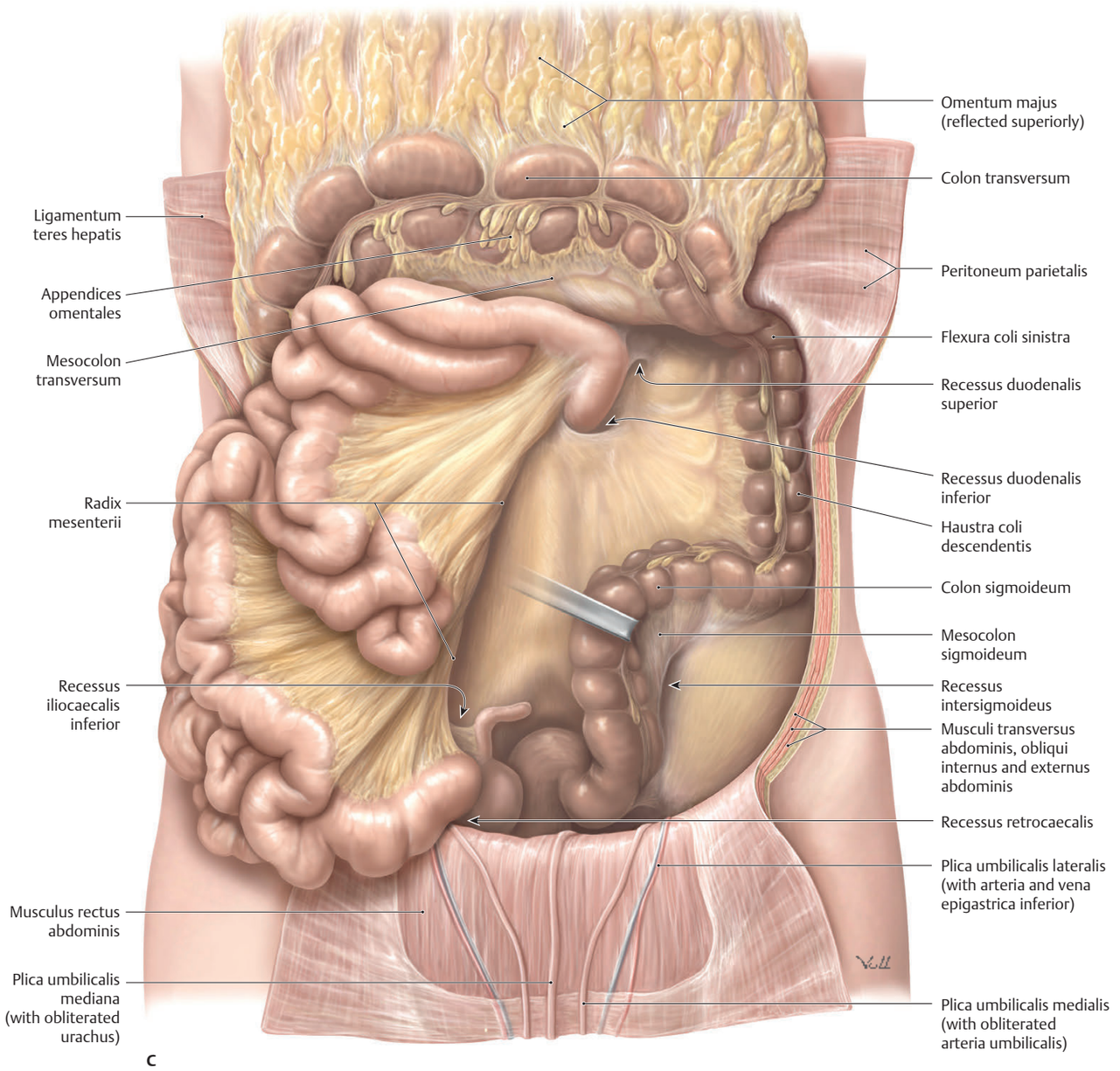


Fig. 15.85 **Dissection of the peritoneal cavity**
Anterior view. **A** Greater sac. *Retracted:* Abdominal wall.
B Infracolic compartment, the portion of the cavitas peritonealis below the attachment of the mesocolon transversum. *Retracted:* Omentum majus and colon transversum.
C Mesenteria and mesenteric recesses in the infracolic compartment. *Retracted:* Omentum majus, colon transversum, intestina tenua, and colon sigmoideum.


Omentum majus (reflected superiorly)
Colon transversum
Ligamentum teres hepatis
Peritoneum parietalis
Appendices omentales
Flexura coli sinistra
Mesocolon transversum
Recessus duodenalis superior
Recessus duodenalis inferior
Radix mesenterii
Haustra coli descendentis
Colon sigmoideum
Mesocolon sigmoideum
Recessus iliocaecalis inferior
Recessus intersigmoideus
Musculi transversus abdominis, obliqui internus and externus abdominis
Recessus retrocaecalis
Plica umbilicalis lateralis (with arteria and vena epigastrica inferior)
Musculus rectus abdominis
Plica umbilicalis mediana (with obliterated urachus)
Plica umbilicalis medialis (with obliterated arteria umbilicalis)
C

Gaster & Bursa Omentalis

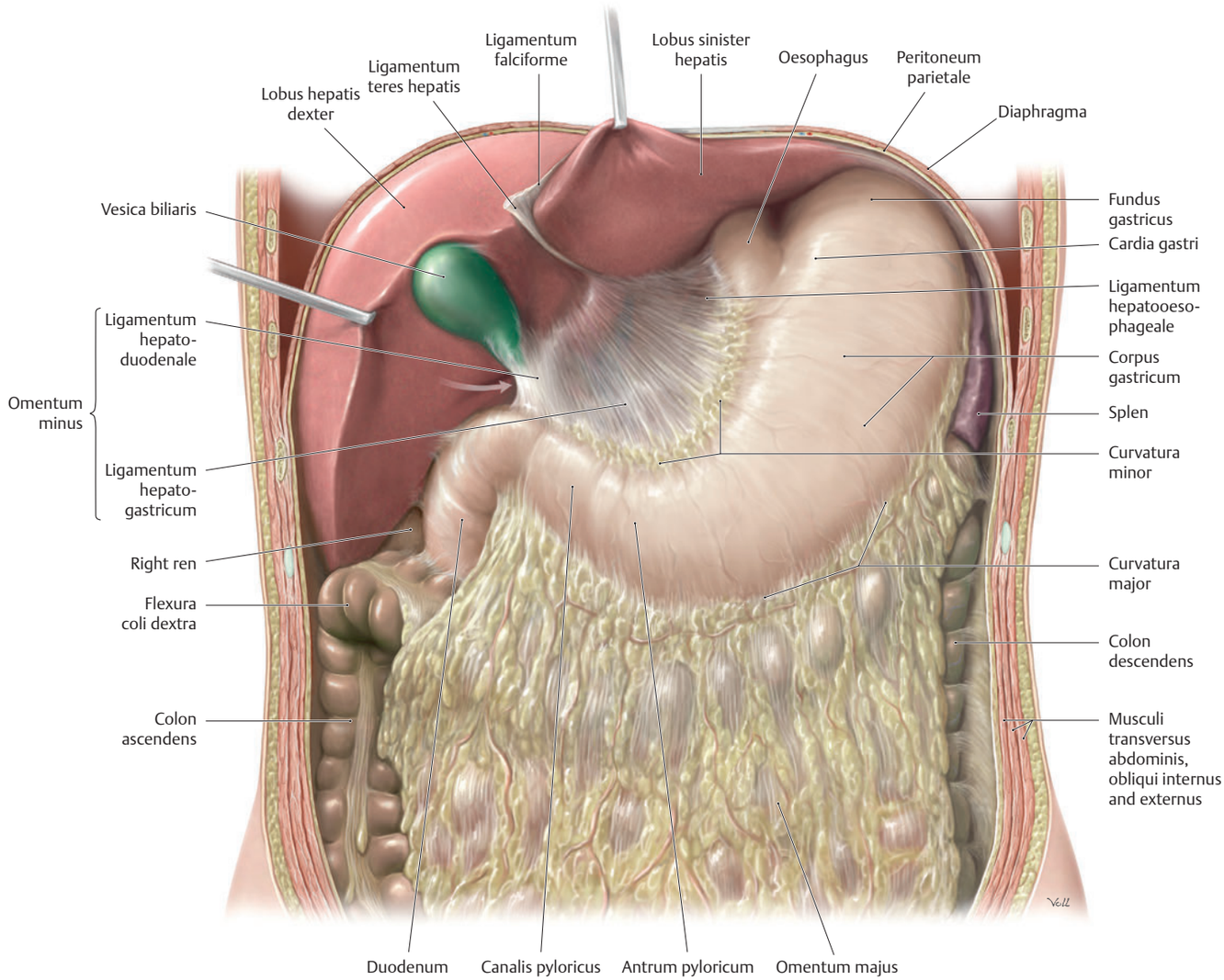


Fig. 15.86 **Gaster in situ**
Anterior view of the opened upper abdomen. Arrow indicates the foramen omentale.

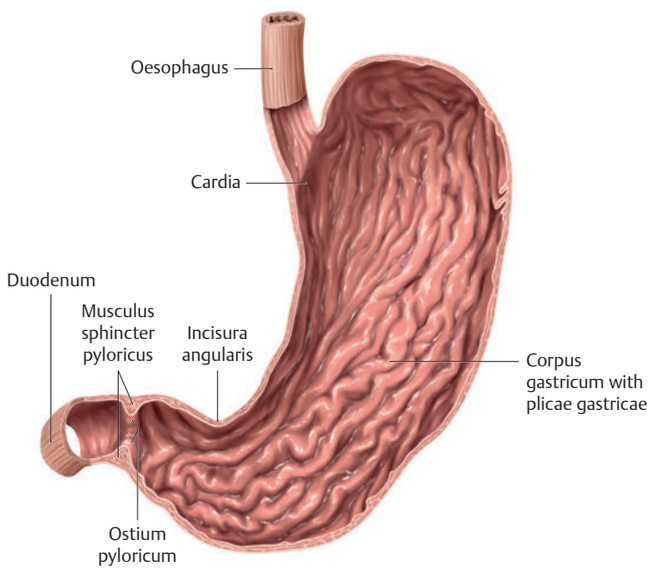


Fig. 15.87 **Gaster**
Anterior view. *Removed:* Anterior wall.

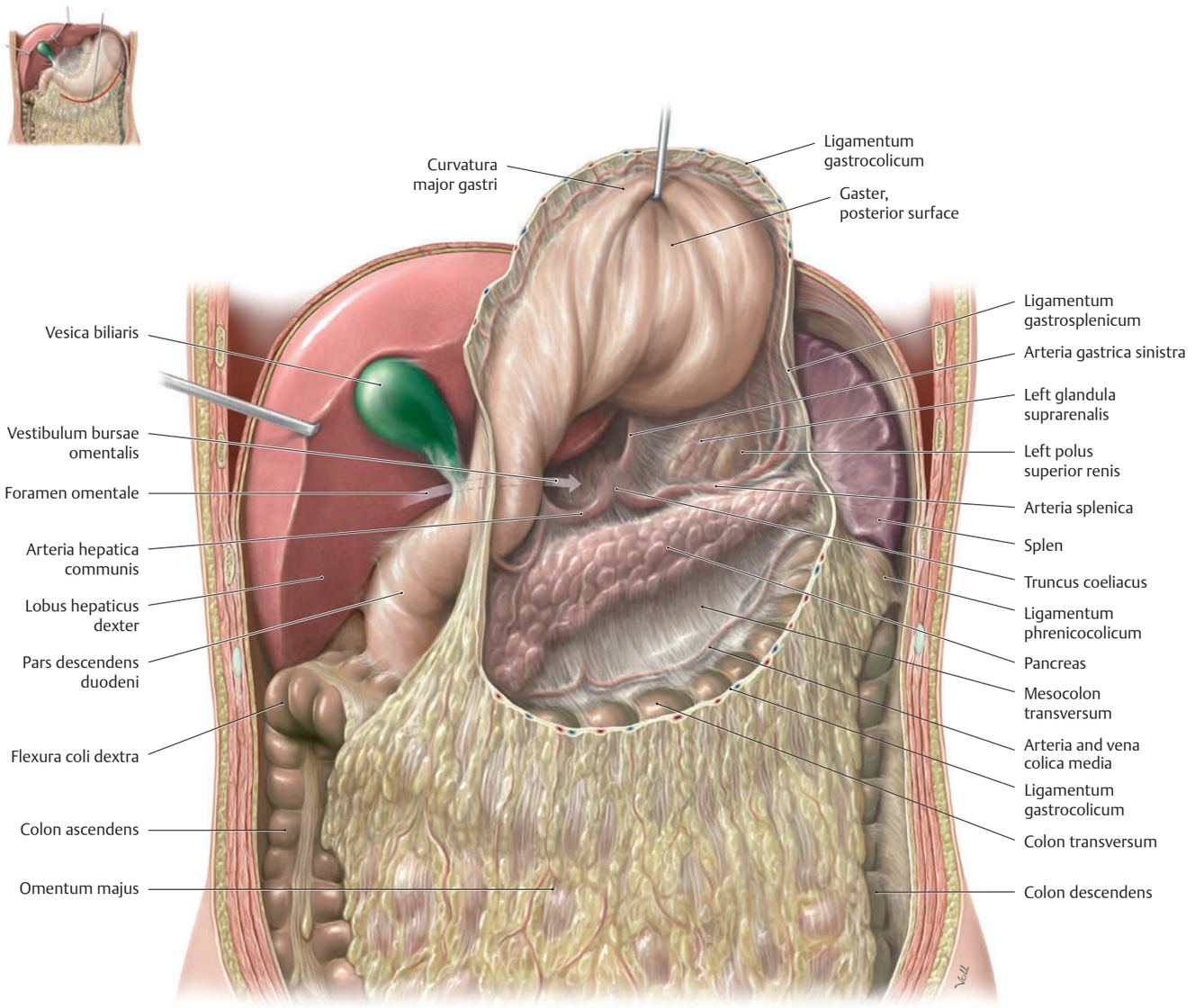


Fig. 15.88 **Bursa omentalis**
Anterior view. *Divided:* Ligamentum gastrocolicum. *Retracted:* Hepar. *Reflected:* Gaster.

Mesenteria (II) & Intestinum

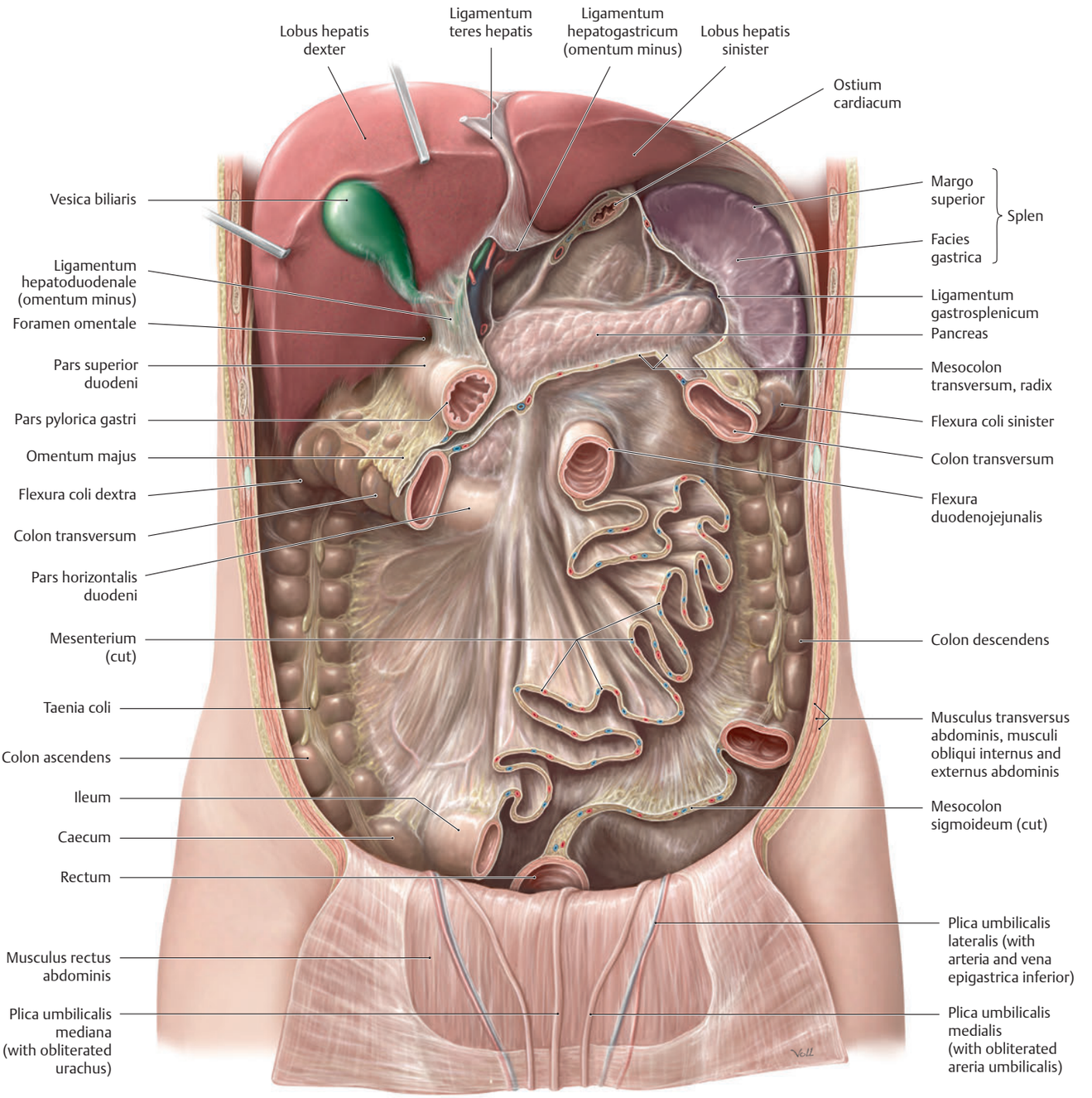


Fig. 15.89 **Mesenteries and organs of the cavitas peritonealis**
Anterior view. *Divided:* Gaster, jejunum, and ileum.
Retracted: Hepar.

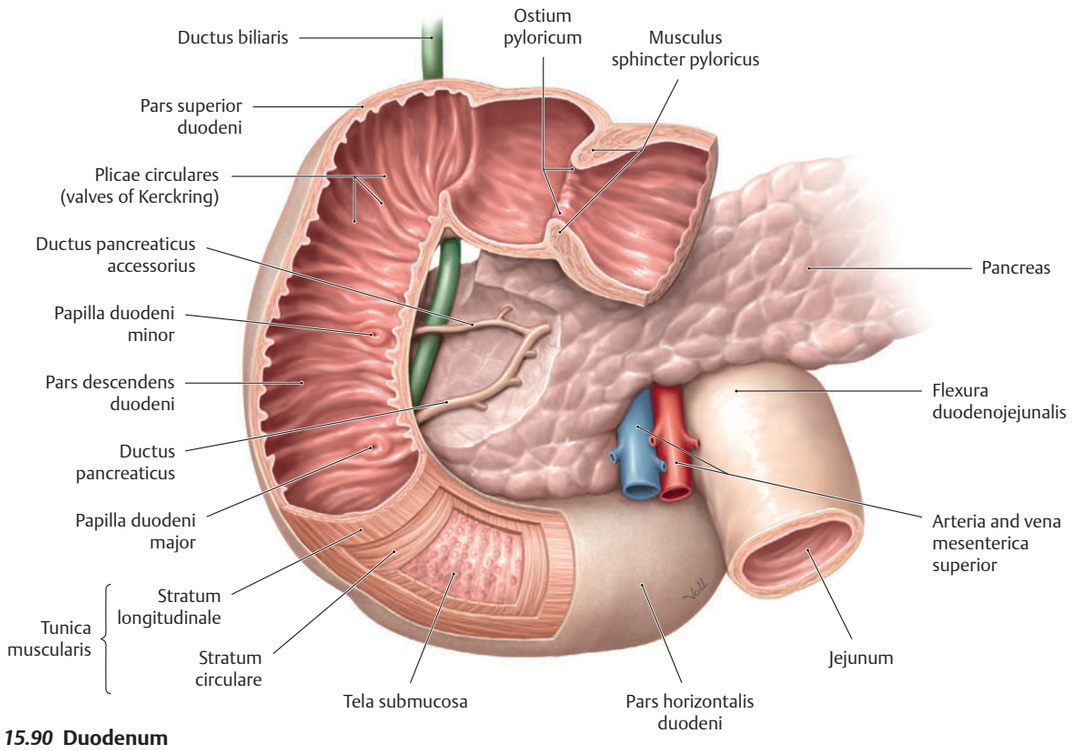


Fig. 15.90 **Duodenum**
Anterior view with the anterior wall opened. The intestinum tenue consists of the duodenum, jejunum, and ileum. The duodenum is primarily retroperitoneal and is divided into four partes: superior, descendens, horizontalis, and ascendens.

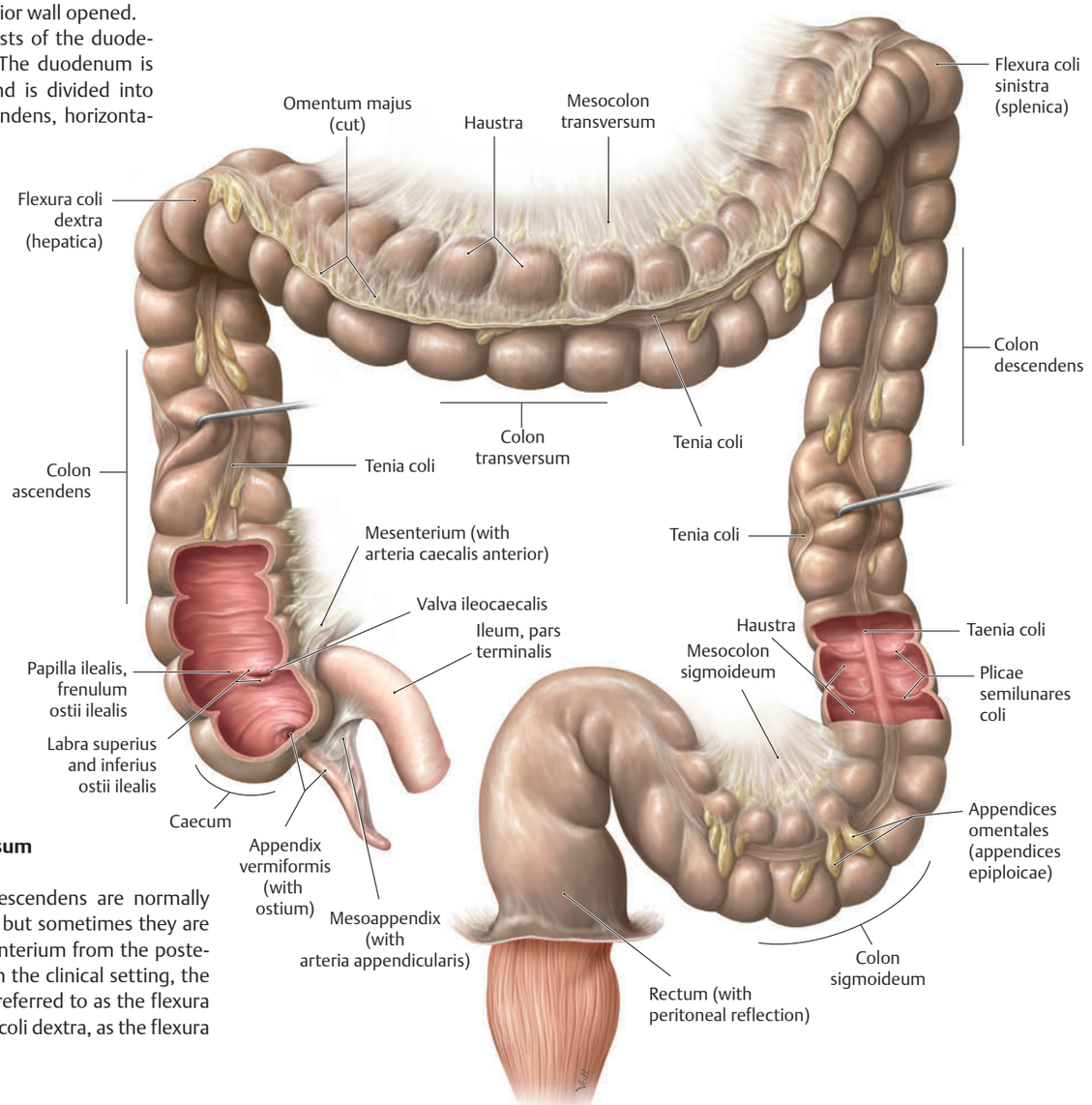


Fig. 15.91 **Intestinum crassum**
Anterior view.
The cola ascendens and descendens are normally secondarily retroperitoneal, but sometimes they are suspended by a short mesenterium from the posterior abdominal wall. Note: In the clinical setting, the flexura coli sinistra is often referred to as the flexura coli splenica and the flexura coli dextra, as the flexura hepatica.

Hepar, Vesica Biliaris, & Biliary Tract

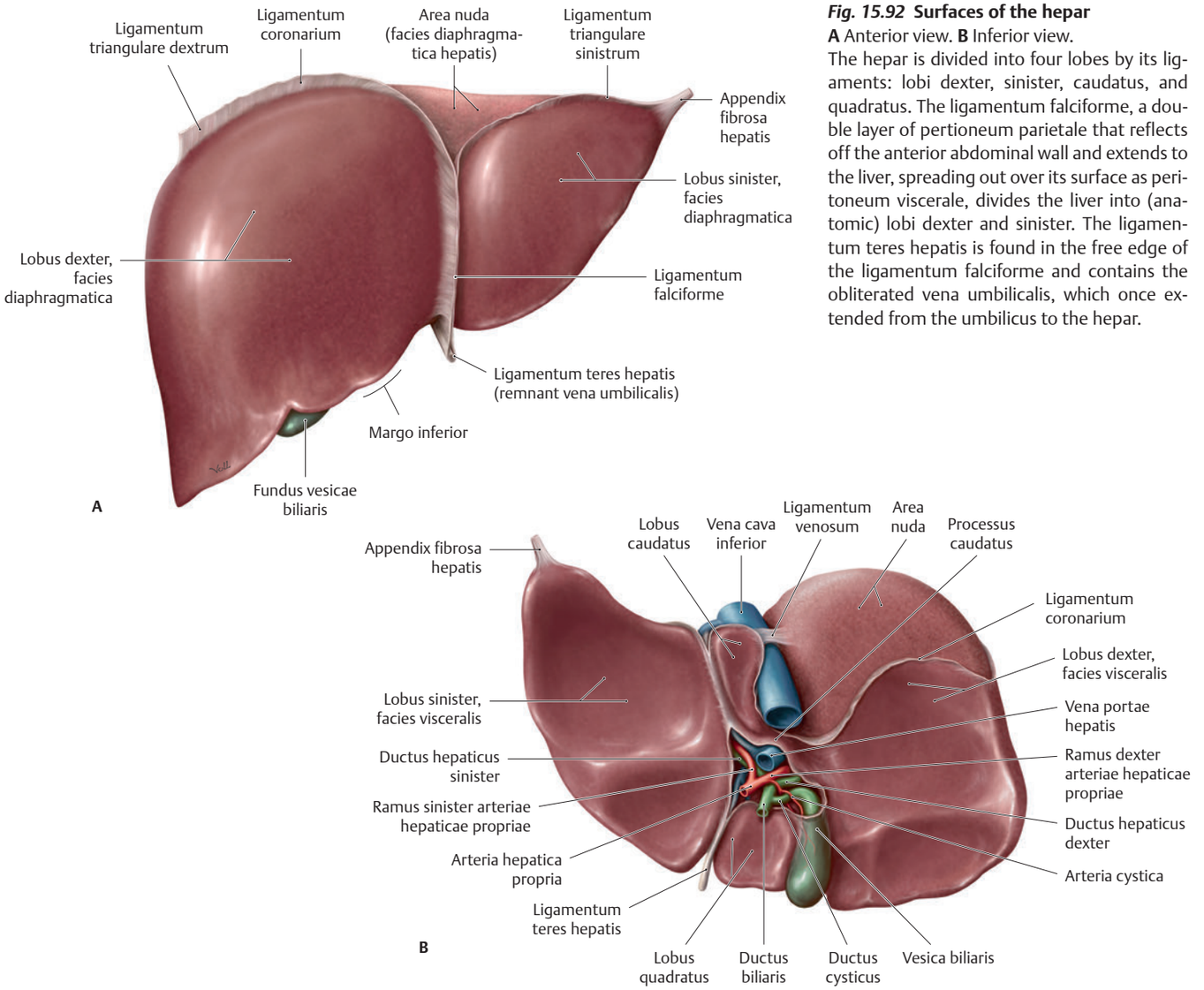


Fig. 15.92 **Surfaces of the hepar**
A Anterior view. **B** Inferior view.
The hepar is divided into four lobes by its ligaments: lobi dexter, sinister, caudatus, and quadratus. The ligamentum falciforme, a double layer of pertioneum parietale that reflects off the anterior abdominal wall and extends to the liver, spreading out over its surface as peritoneum viscerale, divides the liver into (anatomic) lobi dexter and sinister. The ligamentum teres hepatis is found in the free edge of the ligamentum falciforme and contains the obliterated vena umbilicalis, which once extended from the umbilicus to the hepar.

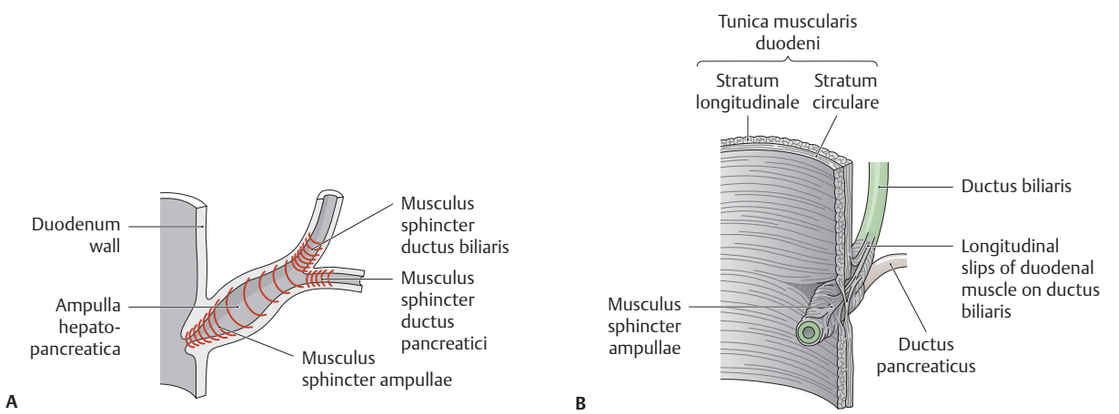


Fig. 15.93 **Biliary sphincter system**
A Musculi sphinctri of the ductus pancreaticus and biliaris. **B** Sphincter system in the duodenal wall.

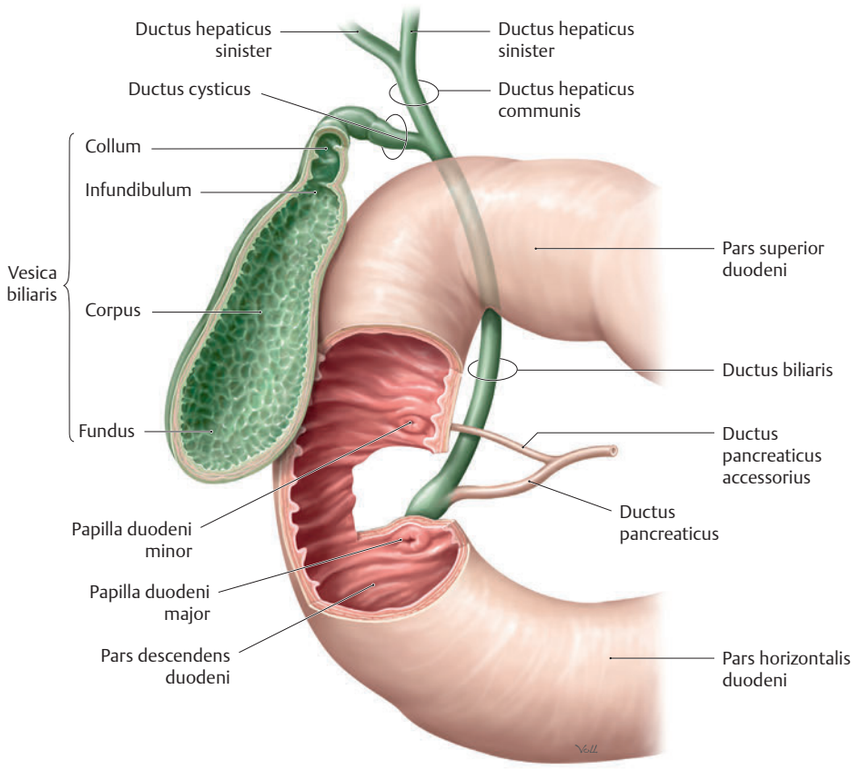
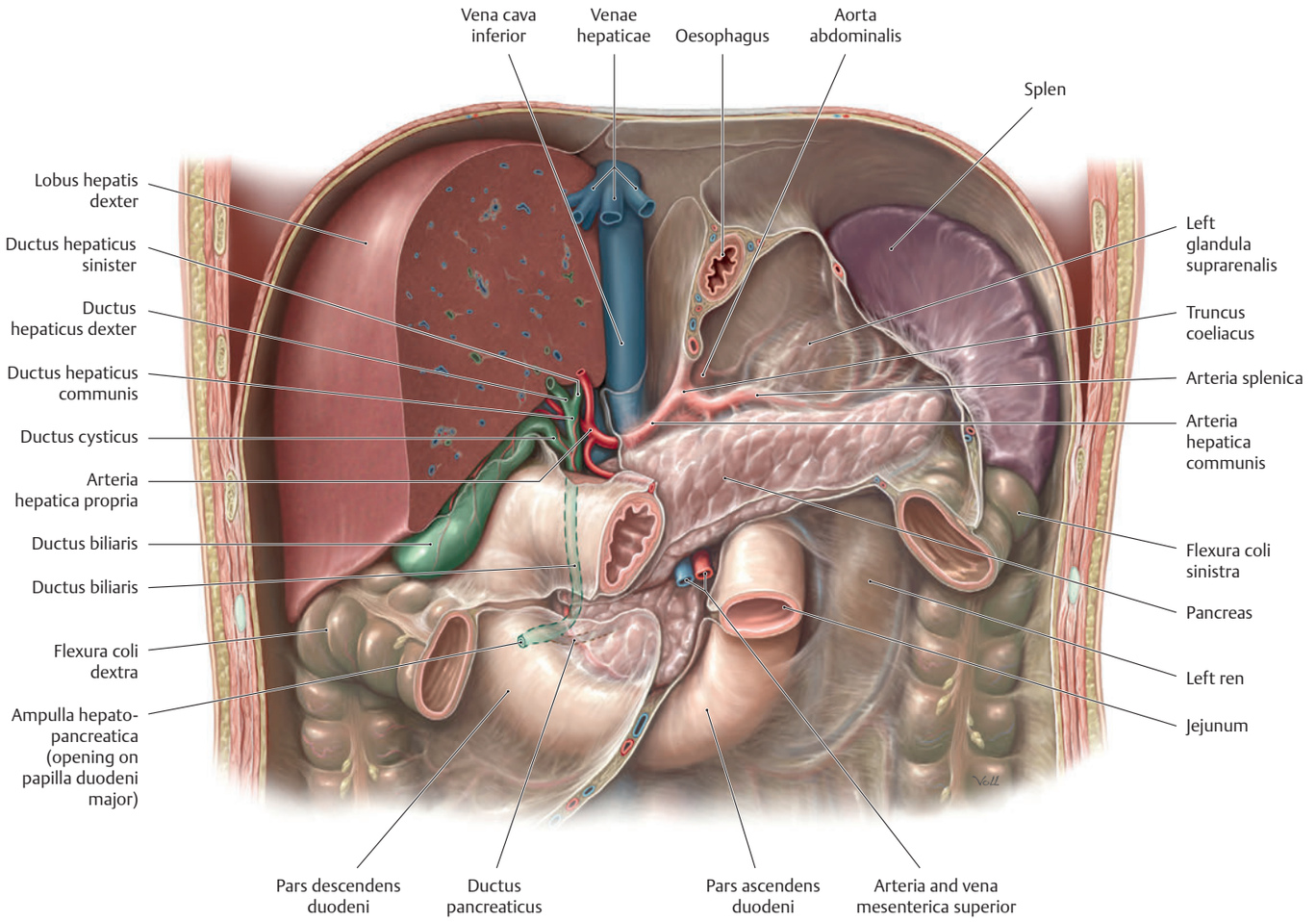


Fig. 15.94 **Extrahepatic bile ducts**
Anterior view. *Opened:* Vesica biliaris and duodenum.

Fig. 15.95 **Biliary tract in situ**
Anterior view. *Removed:* Gaster, intestinum tenue, colon transversum, and large portions of the hepar. The vescia biliaris is intraperitoneal and covered by peritoneum viscerale where it is not attached to the hepar.



Aorta Abdominalis & Truncus Coeliacus

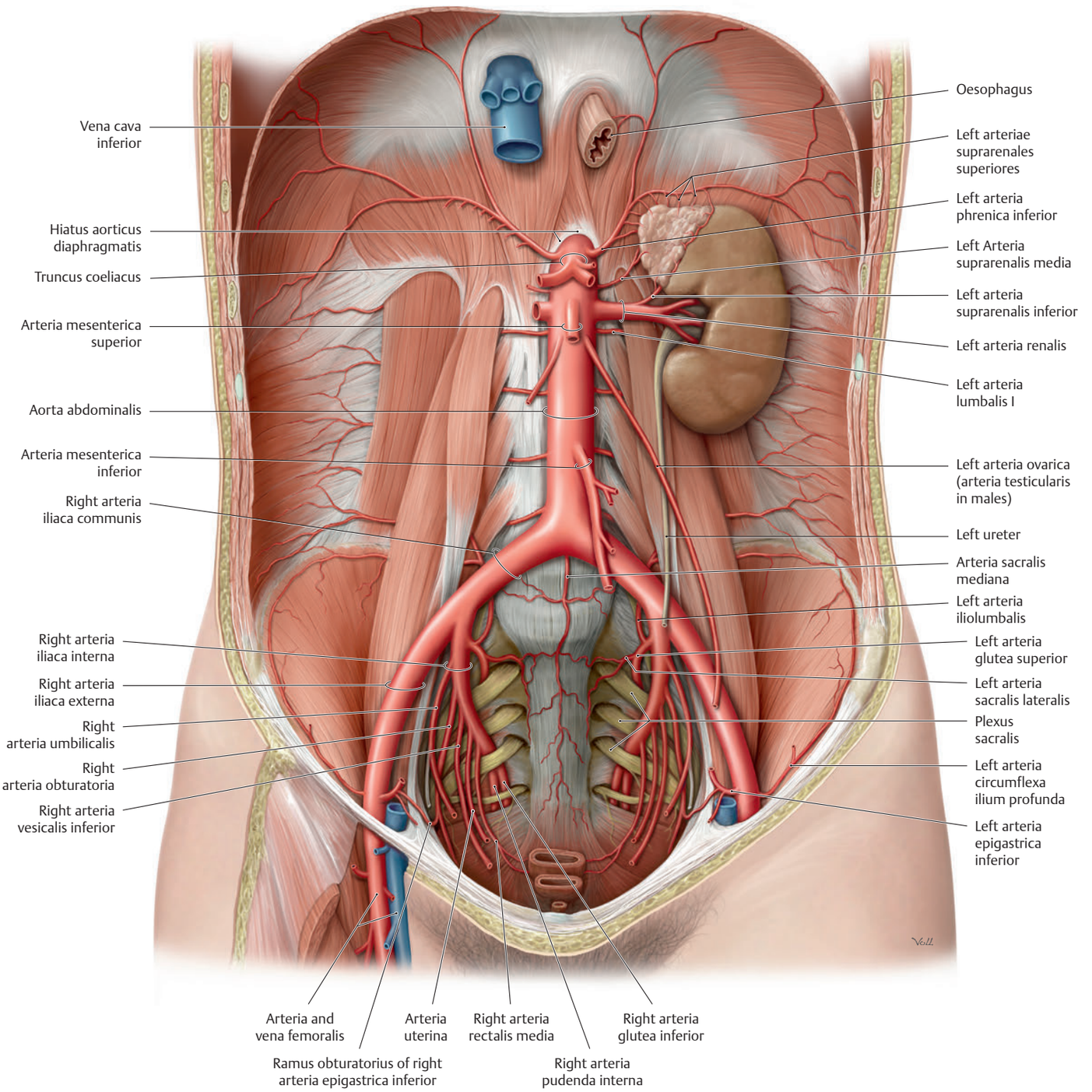


Fig. 15.96 **Abdominal aorta**
Anterior view of the female abdomen. *Removed:* All organs except the left ren and glandula suprarenalis. The aorta abdominalis is the distal continuation of the aorta thoracica (see **Fig. 15.43**, p. 414). It enters the abdomen at the T12 level and bifurcates into the arteriae iliacae communes at L4.

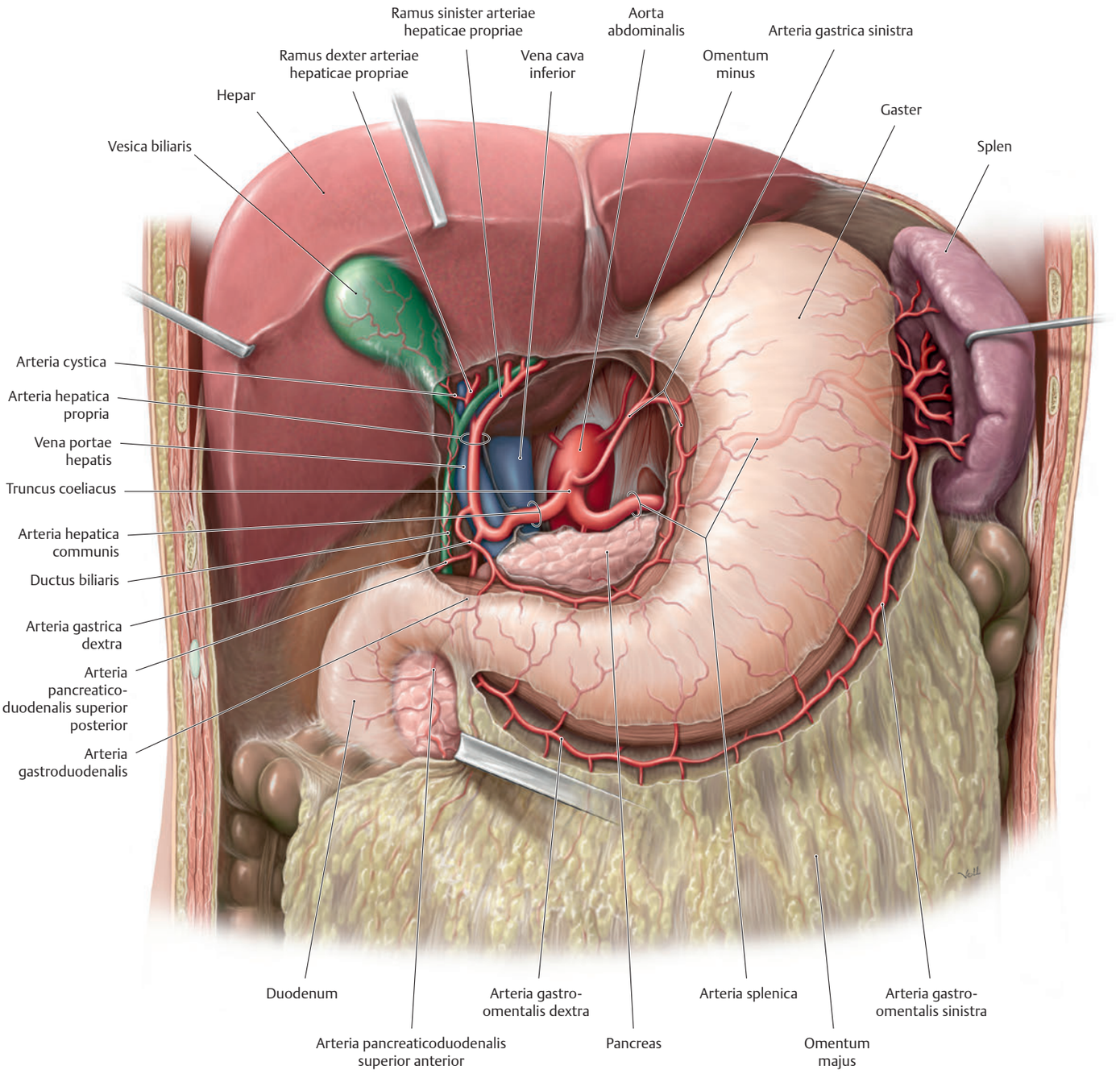


Fig. 15.97 **Truncus coeliacus: Gaster, hepar, and vesica biliaris**
Anterior view. *Opened:* Omentum minus. *Incised:* Omentum majus. The truncus coeliacus arises from the aorta abdominalis at about the level of T12.

Arteriae Mesentericae Superior & Inferior

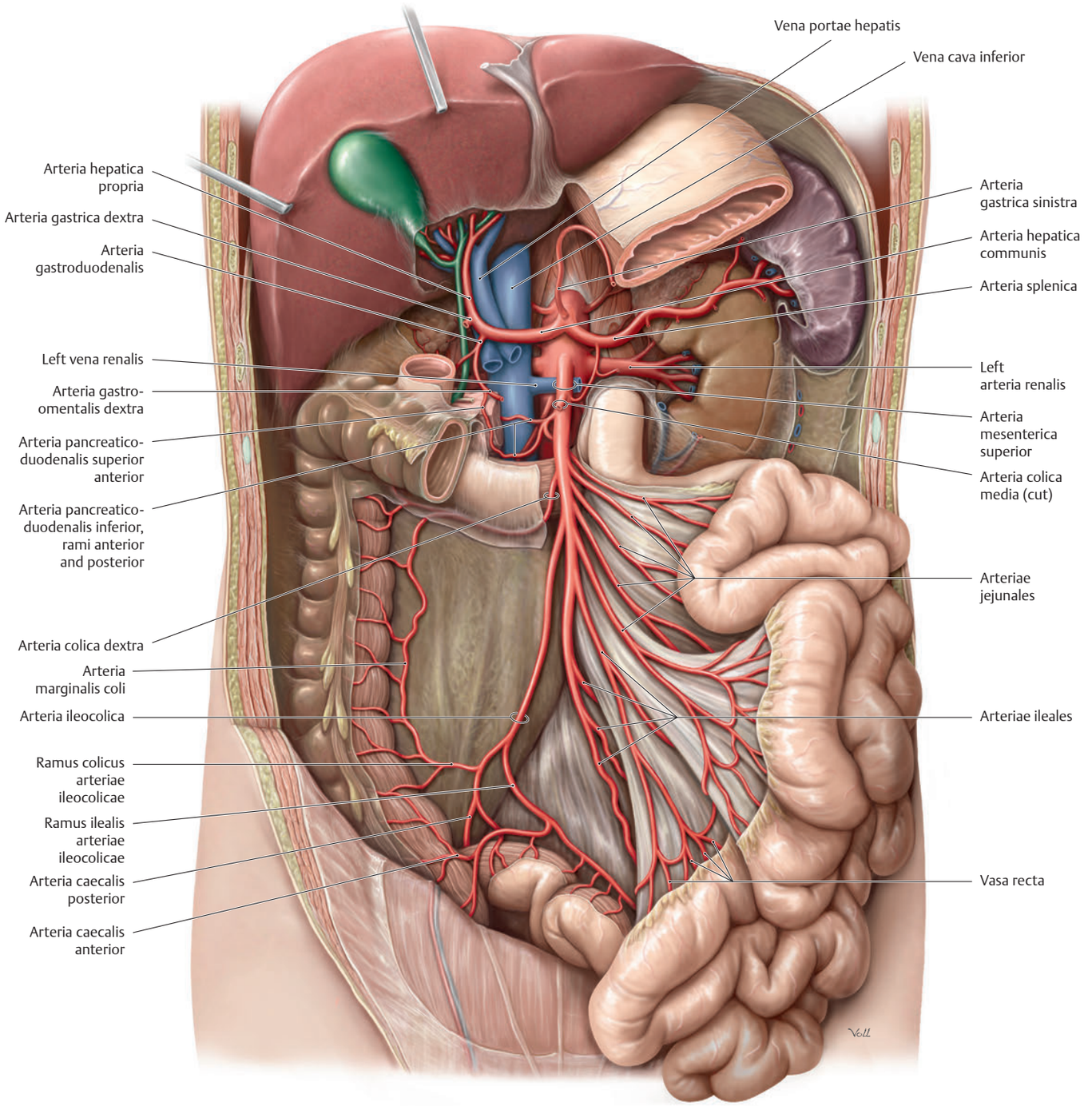


Fig. 15.98 **Arteria mesenterica superior**
Anterior view. *Partially removed:* Gaster, duodenum, and peritoneum. *Reflected:* Hepar and vesica biliaris. *Note:* The arteria colica media has been truncated (see **Fig. 15.99**). The arteriae mesentericae superior and inferior arise from the aorta opposite L2 and L3, respectively.

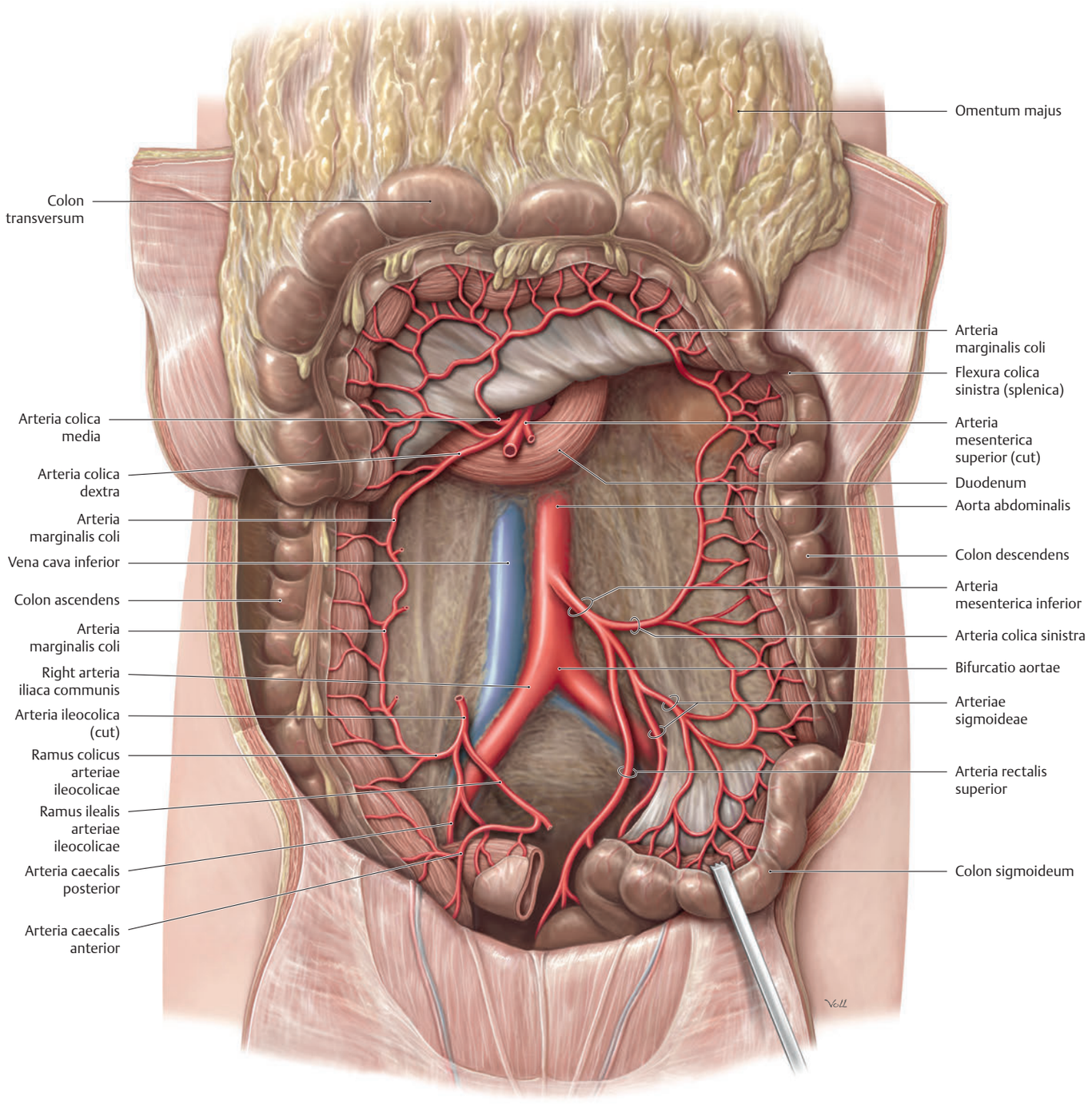


Fig. 15.99 **Arteria mesenterica inferior**
Anterior view. *Removed:* Jejunum and ileum.
Reflected: Colon transversum.

Veins of the Abdomen

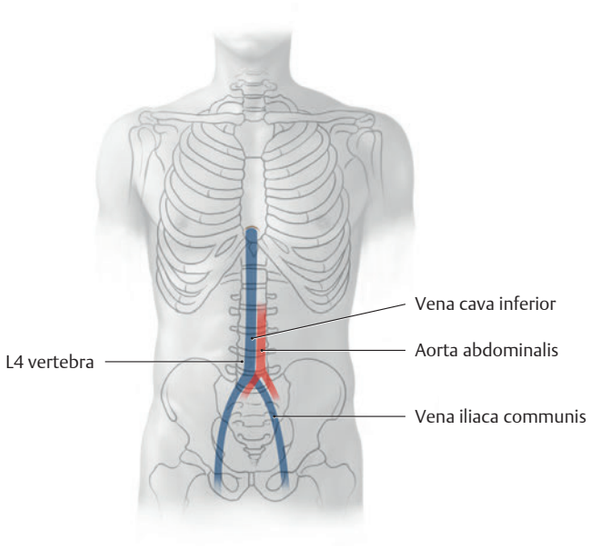


Fig. 15.100 **Location of the vena cava inferior**
Anterior view.

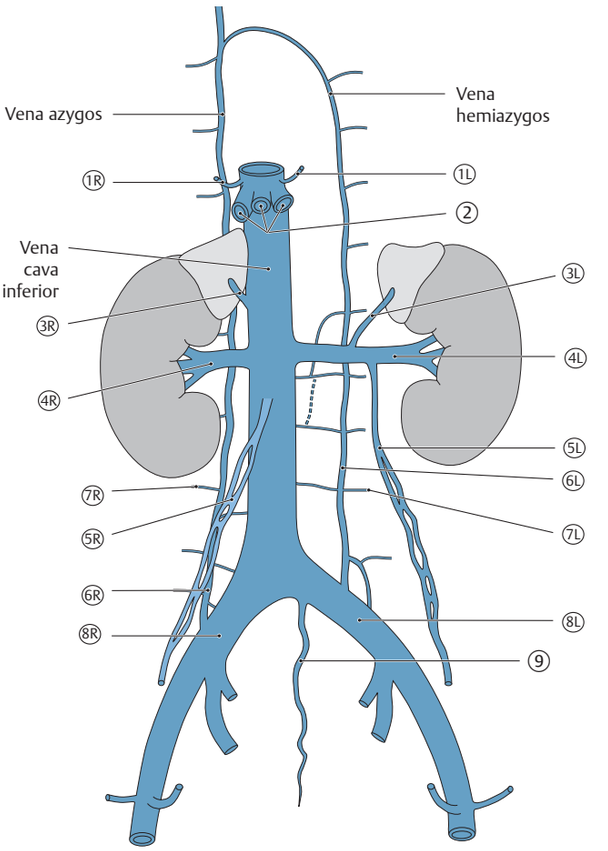


Fig. 15.101 **Tributaries of the vena cava inferior**
Schematic. See **Table 15.16**.

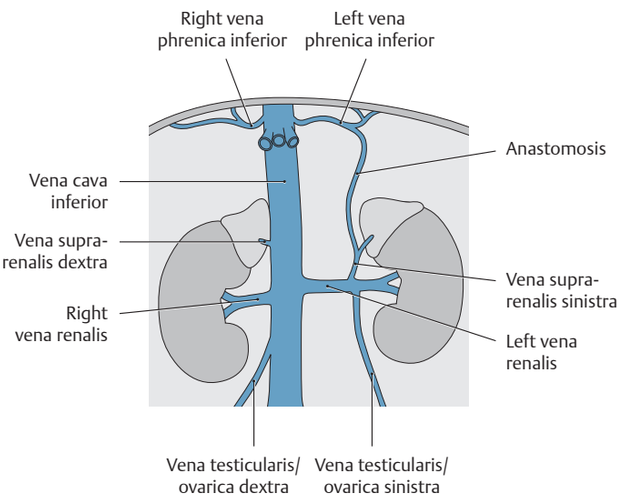


Fig. 15.102 **Tributaries of the venae renales**
Anterior view.

Table 15.16 **Tributaries of the vena cava inferior**

1R	1L	Venae phrenicae inferiores (paired)
2		Venae hepaticae (3)
3R	3L	Venae suprarenales (the vena dextra is a direct tributary)
4R	4L	Venae renales (paired)
5R	5L	Venae testiculares/ovaricae (the vena dextra is a direct tributary)
6R	6L	Vena lumbales ascendentes (paired), not direct tributaries
7R	7L	Venae lumbales
8R	8L	Venae iliacae communes (paired)
9		Vena sacralis mediana

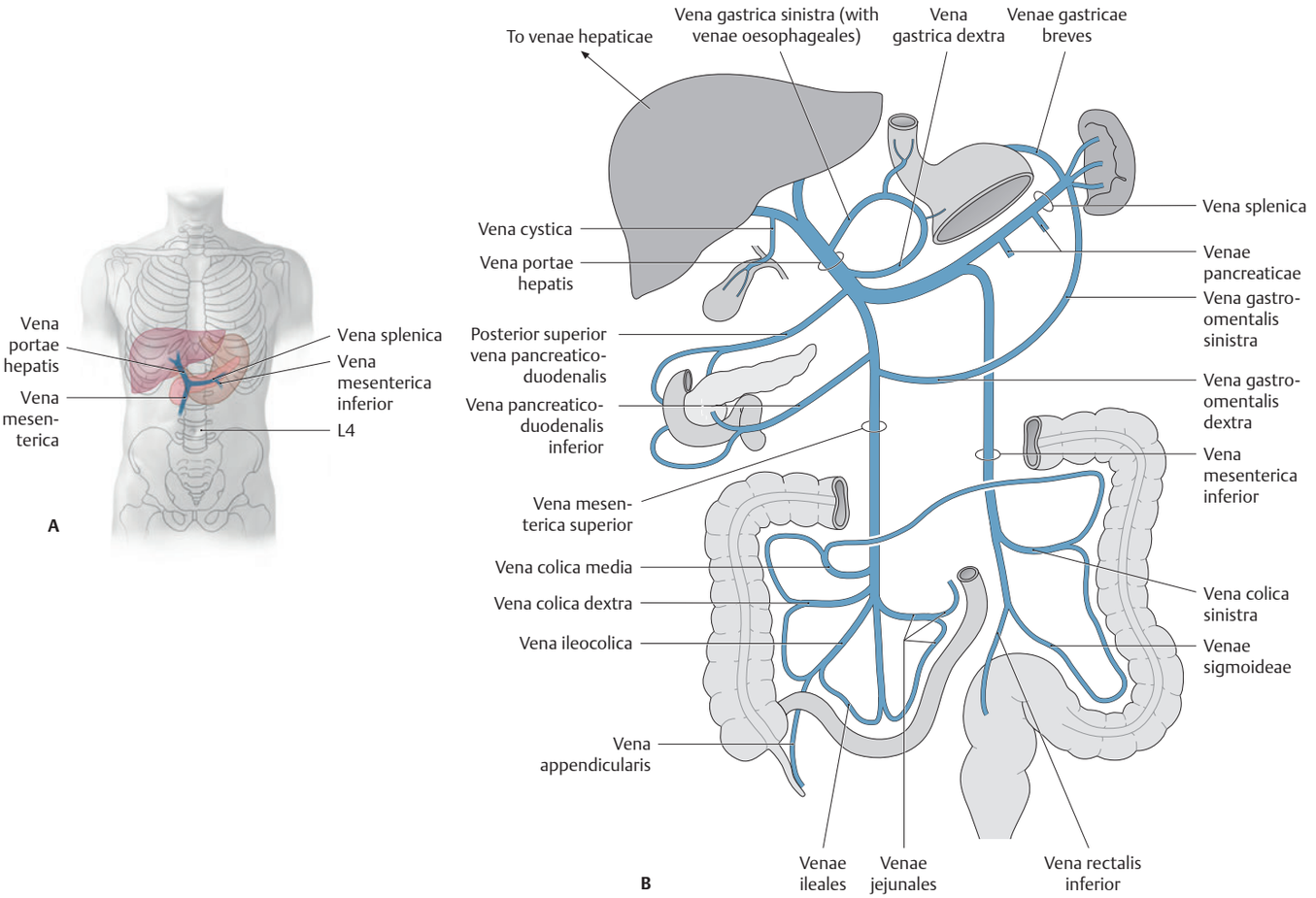


Fig. 15.103 **Vena portae hepatis**
The vena portae hepatis drains venous blood from the abdominopelvic organs supplied by the truncus coeliacus and arteriae mesentericae superior and inferior.
A Location, anterior view.
B Vena portae hepatis distribution.
C Collateral pathways between the portal system and the heart. When the portal system is compromised, the vena portae hepatis can divert blood away from the liver back to its supplying veins, which return this nutrient-rich blood to the heart via the venae cavae. The red arrows indicate the flow reversal in the (1) venae oesophageales, (2) venae paraumbilicales, (3) venae colicae, and (4) venae rectales mediae and inferiores.

Vena Cava Inferior & Venae Mesentericae Inferiores

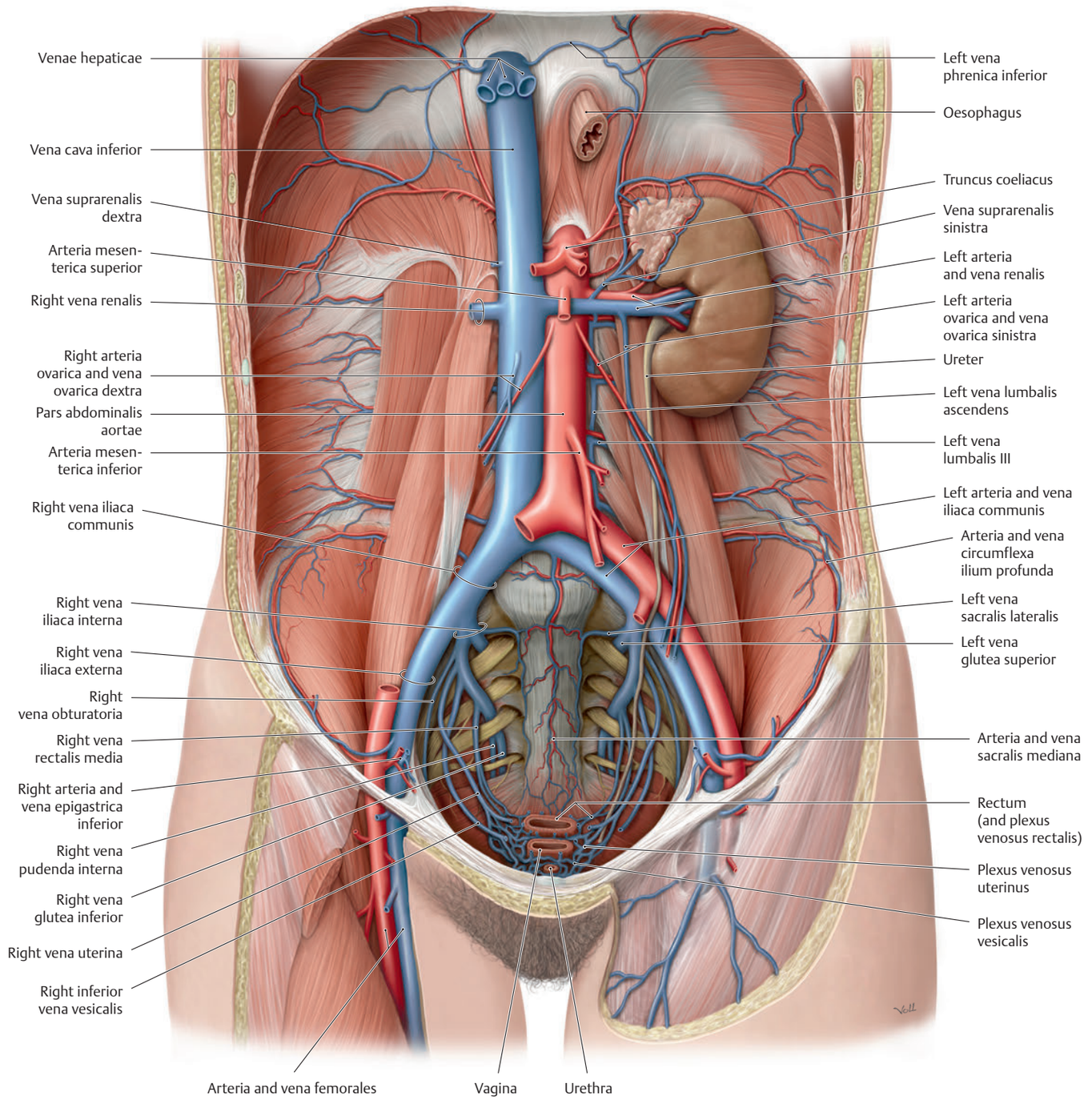


Fig. 15.104 **Vena cava inferior**
Anterior view of the female abdomen. *Removed:* All organs except the left ren and glandula suprarenalis.

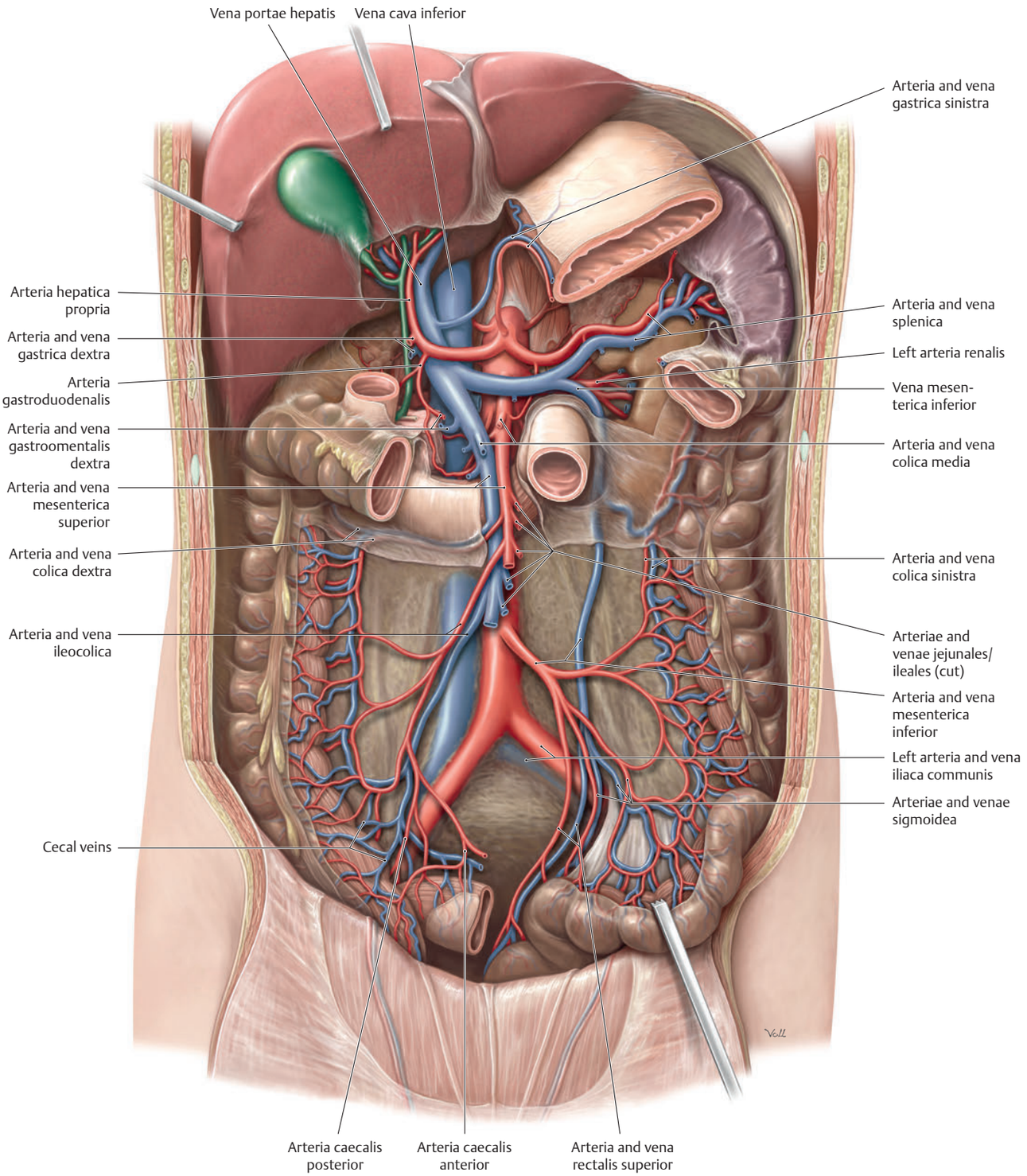


Fig. 15.105 **Vena mesenterica inferior**
Anterior view. *Partially removed:* Gaster, duodenum, and peritoneum. *Removed:* Pancreas, omentum majus, colon transversum, and intestinum tenue. *Reflected:* Hepar and vesica biliaris.
The vena mesenterica inferior is part of the portal system.

Autonomic Plexuses & Sectional Anatomy of the Abdomen

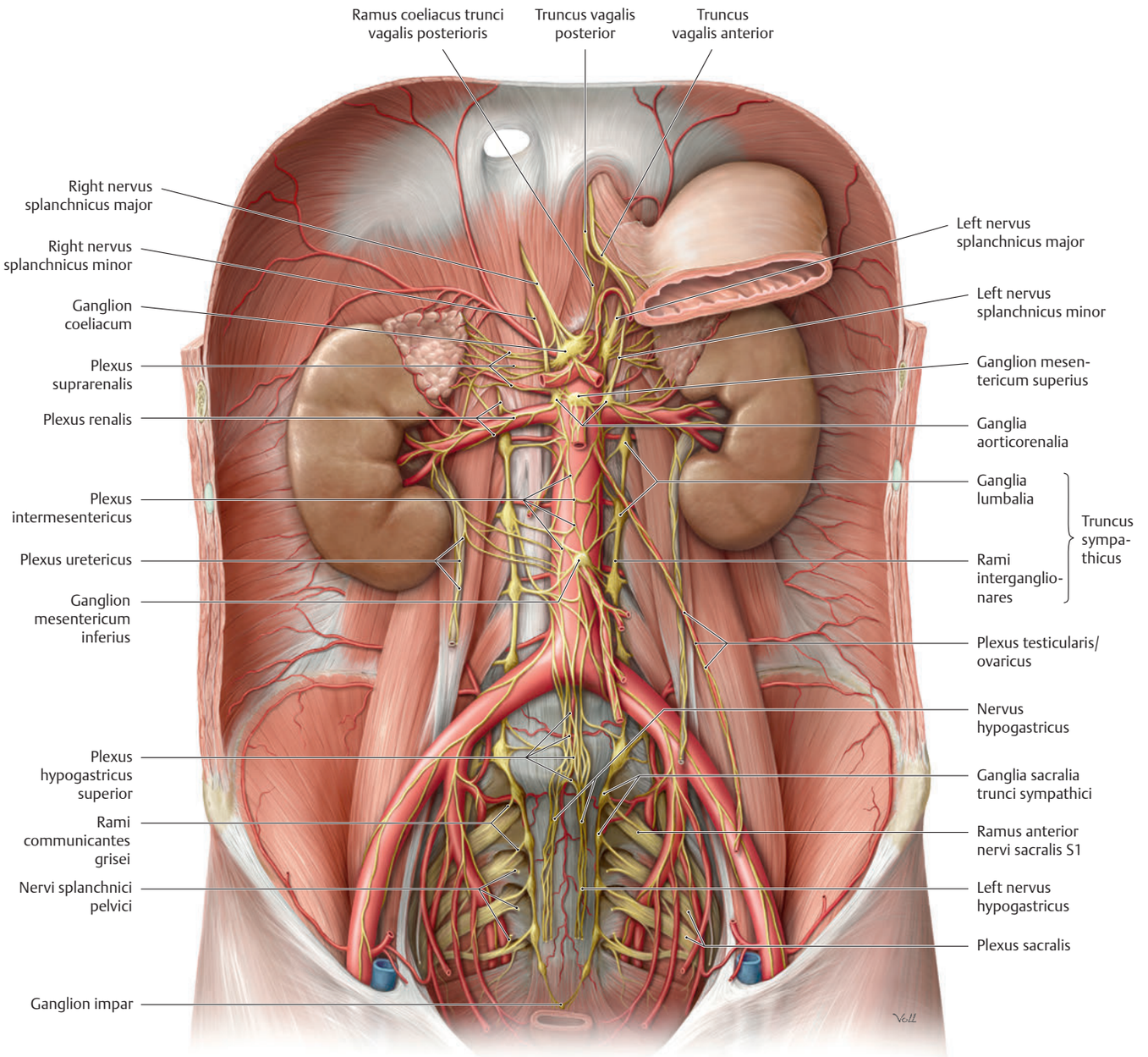
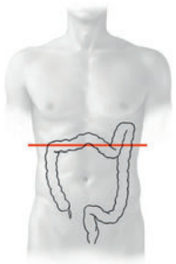
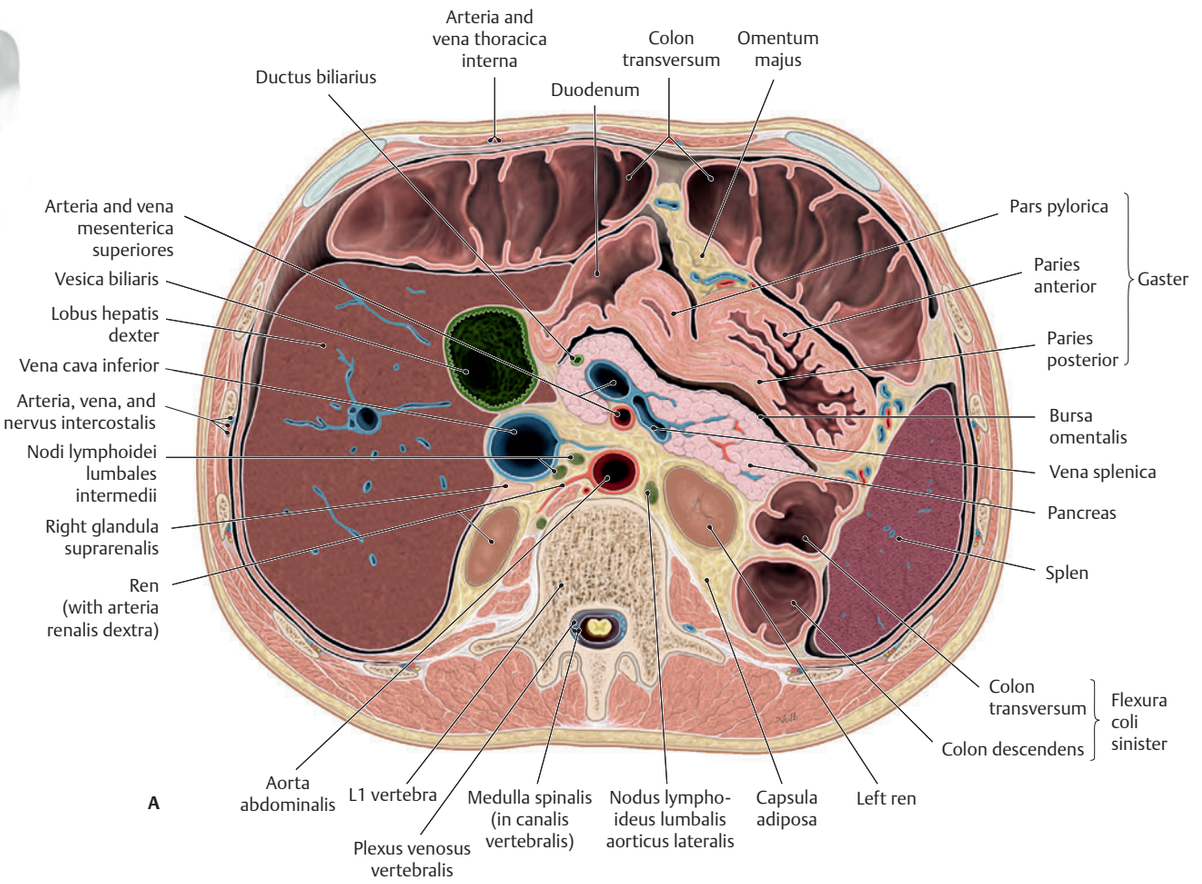
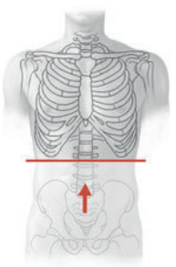


Fig. 15.106 **Autonomic plexuses in the abdomen and pelvis**
Anterior view of the male abdomen and pelvis. *Removed:* Peritoneum, majority of the gaster, and all other abdominal organs except rena and glandulae suprarenales.







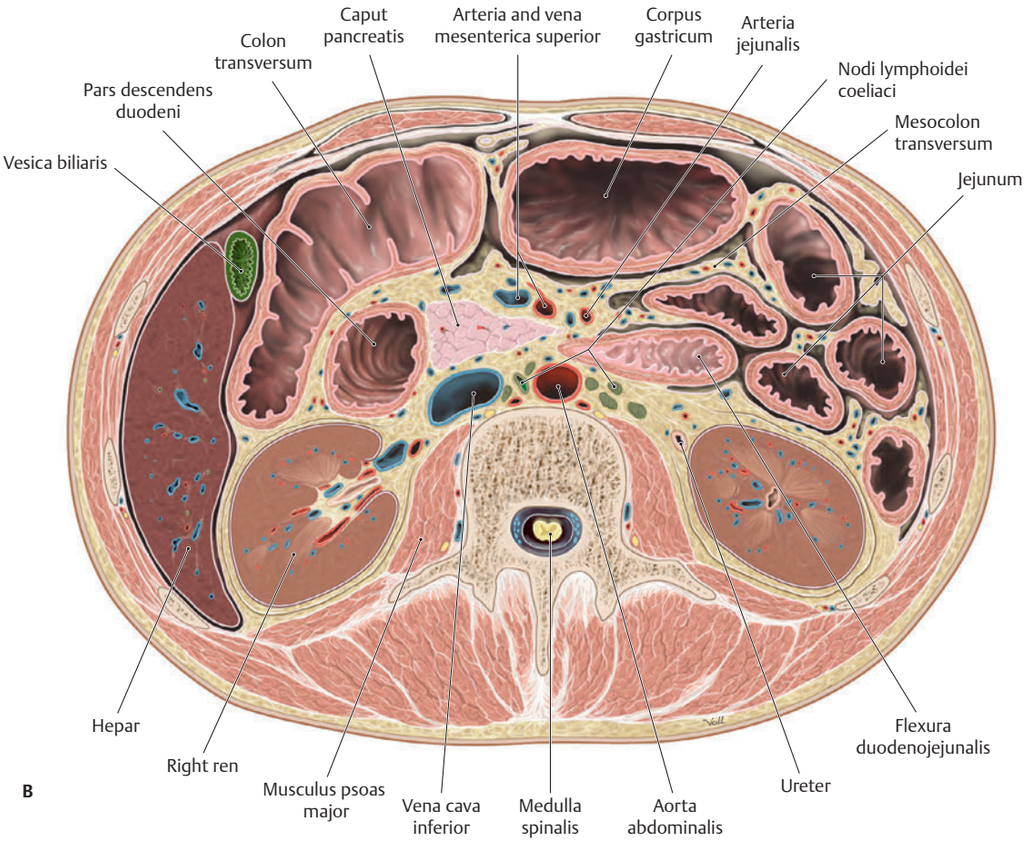


Fig. 15.107 **Transverse sections of the abdomen**
Inferior view. **A** Section through L1 vertebra. **B** Section through L2 vertebra.

Cingulum Pelvicum & Ligaments of the Pelvis

Fig. 15.108 **Cingulum pelvicum**
Anterosuperior view. The cingulum pelvicum surrounds the pelvis, the region of the body inferior to the abdomen. It consists of the two ossa coxae and the os sacrum that together connect the columna vertebralis to the femur. The stability of the cingulum pelvicum is necessary for the transfer of trunk loads to the lower limb, which occurs in normal gait.

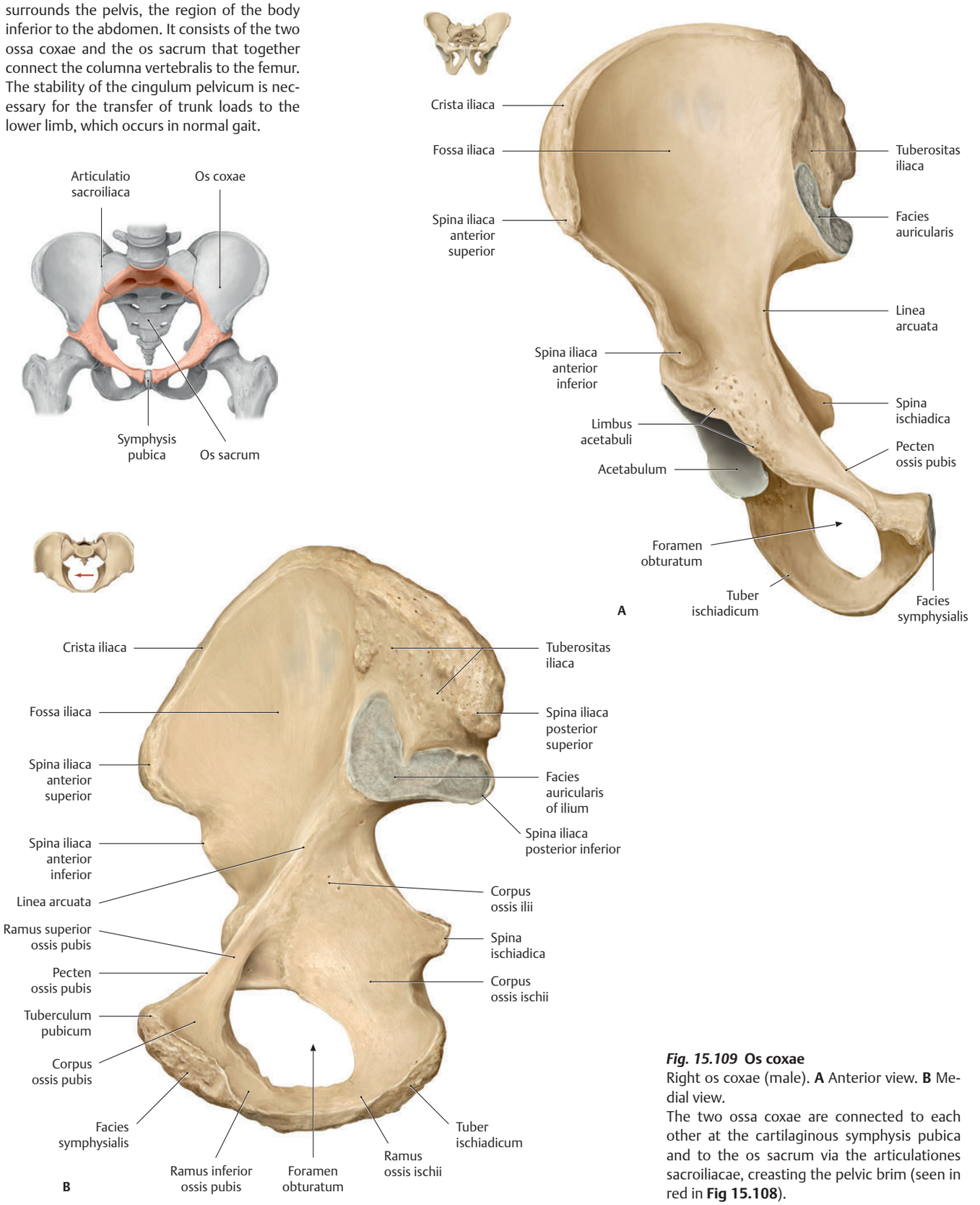


Fig. 15.109 **Os coxae**
Right os coxae (male). **A** Anterior view. **B** Medial view.
The two ossa coxae are connected to each other at the cartilaginous symphysis pubica and to the os sacrum via the articulationes sacroiliacae, creasting the pelvic brim (seen in red in **Fig 15.108**).

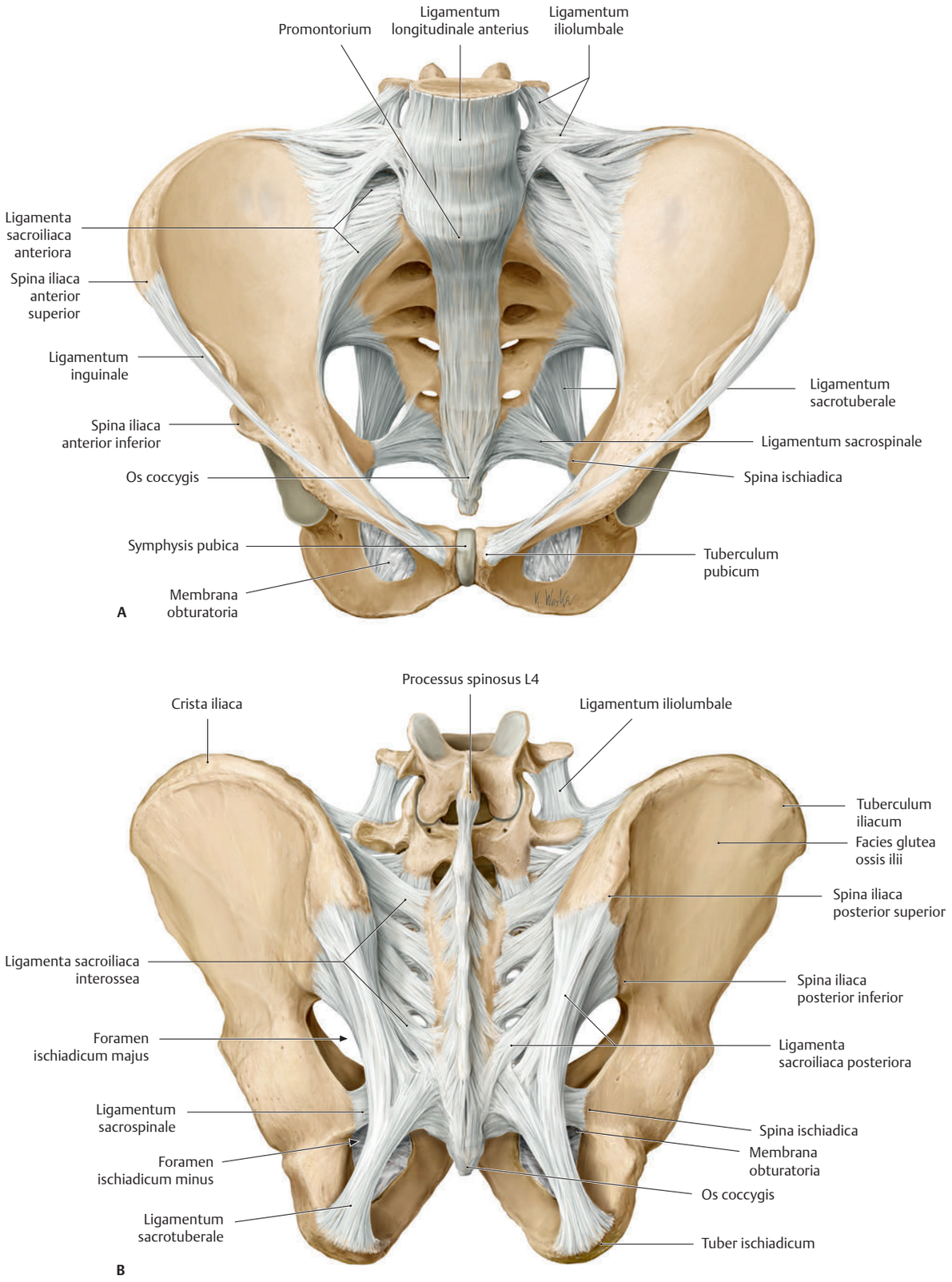


Fig. 15.110 **Ligaments of the pelvis**
Male pelvis. **A** Anterosuperior view. **B** Posterior view. *Removed on the right side:* some of the ligamenta sacroiliaca posteriora to reveal the ligamenta sacroiliaca interossea.

Contents of the Pelvis

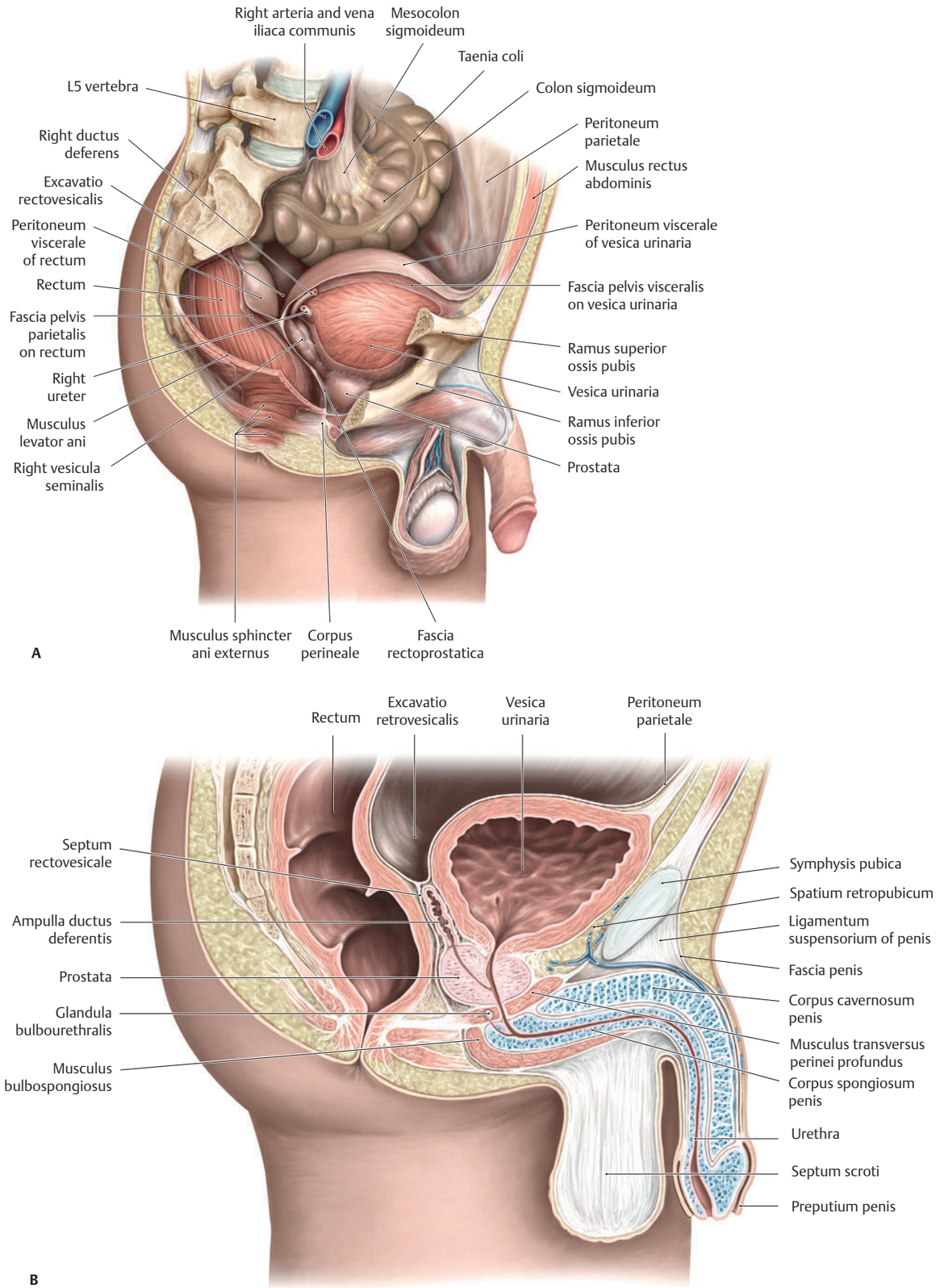
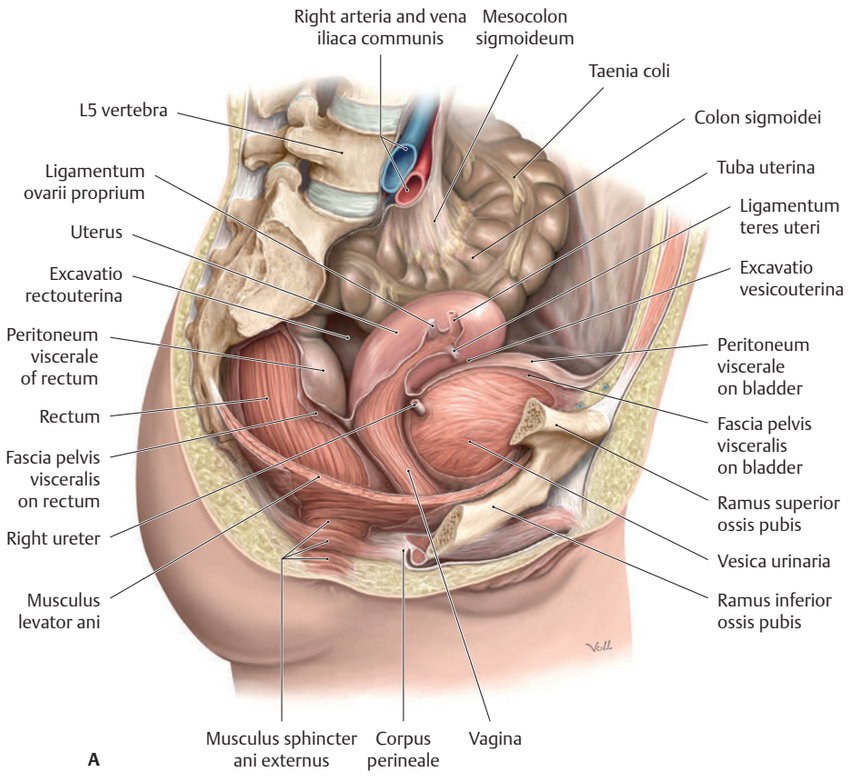


Fig. 15.111 **Male pelvis**
A Parasagittal section, viewed from the right side. **B** Midsagittal section, viewed from the right side.



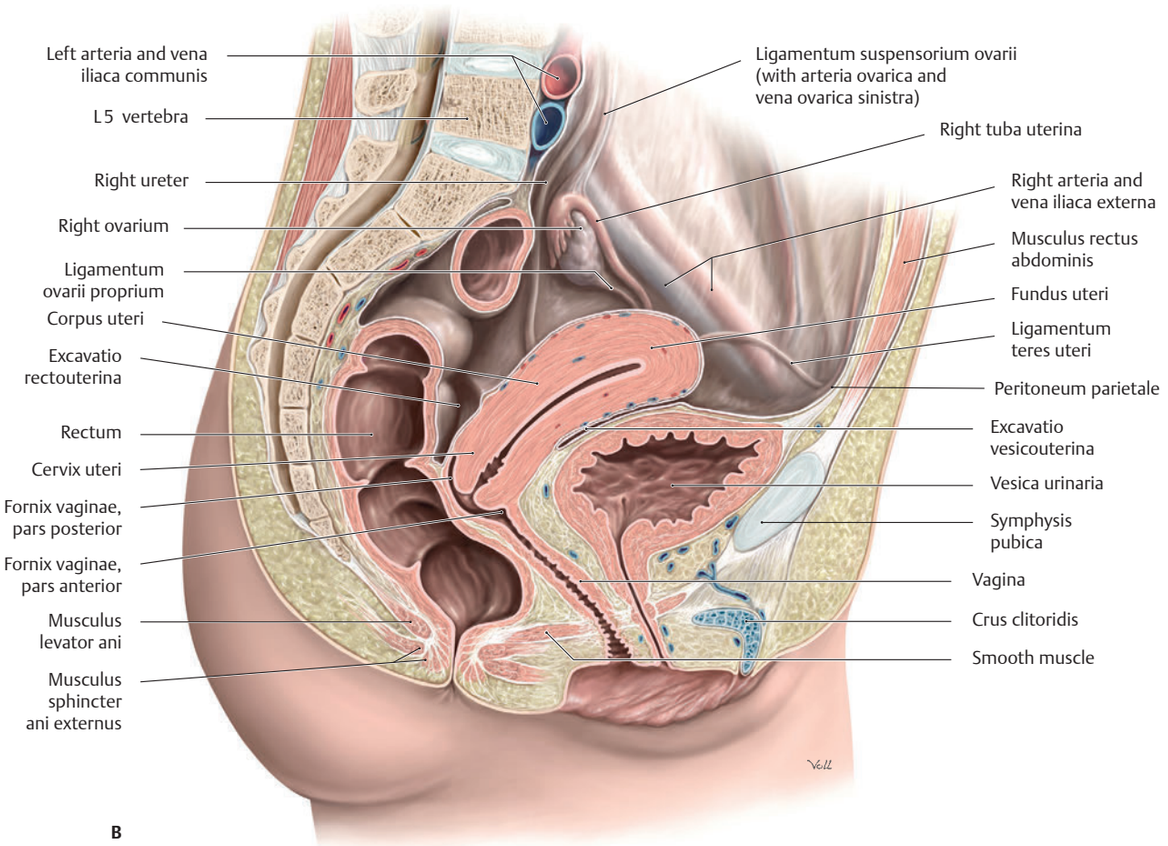
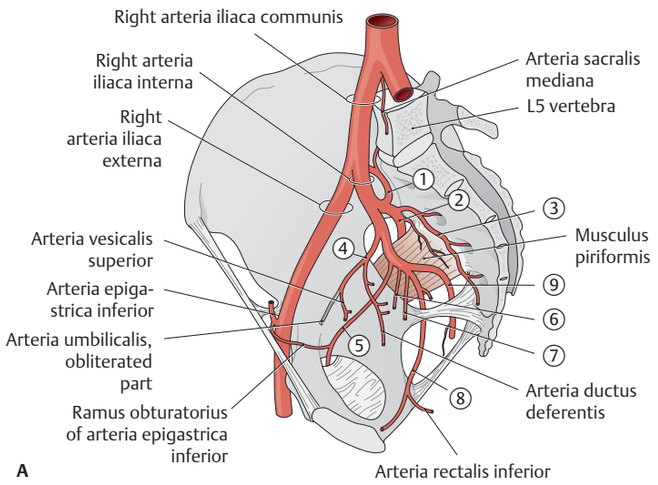


Fig. 15.112 **Female pelvis**
A Parasagittal section, viewed from the right side. **B** Midsagittal section, viewed from the right side.

Arteries & Veins of the Pelvis



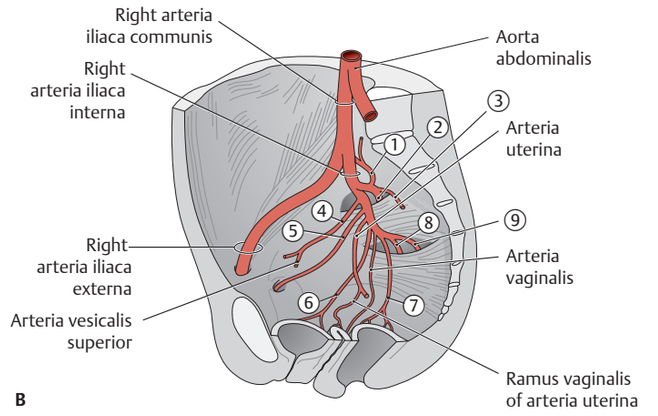
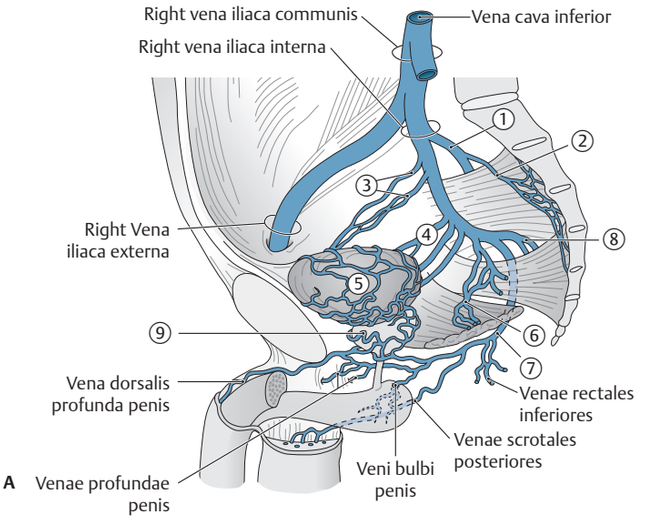


Fig. 15.113 **Arteries of the pelvis**
A Male pelvis. **B** Female pelvis. See **Table 15.17**.



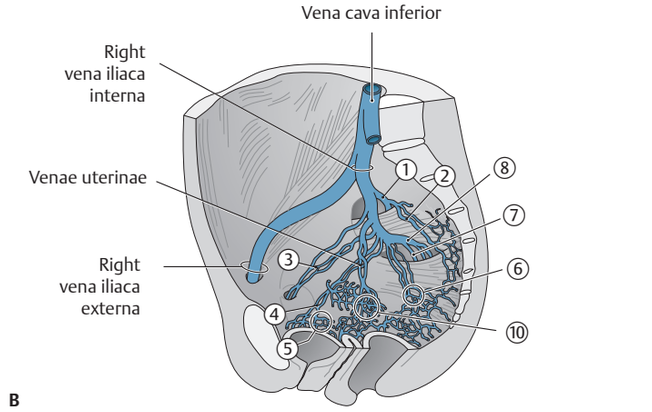


Fig. 15.114 **Veins of the pelvis**
A Male pelvis. **B** Female pelvis. See **Table 15.18**.

Table 15.17 Branches of the arteria iliaca interna

The arteria iliaca interna gives off five parietal (pelvic wall) and four visceral (pelvic organs) branches.* Parietal branches are shown in italics.

Branches		
①	*Arteria iliolumbalis*	
②	*Arteria glutea superior*	
③	*Arteria sacralis lateralis*	
④	Arteria umbilicalis	A. ductus deferentis
		Arteria vesicalis superior
⑤	*Arteria obturatoria*	
⑥	Arteria vesicalis inferior	
⑦	Arteria rectalis media	
⑧	Arteria pudenda interna	Arteria rectalis inferior
⑨	*Arteria glutea inferior*	

* In the female pelvis, the arteriae uterina and vaginalis arise directly from the anterior division of the arteria iliaca interna.

Table 15.18 Venous drainage of the pelvis

Tributaries	
①	Vena glutea superior
②	Vena sacralis lateralis
③	Venae obturatoriae
④	Venae vesicales
⑤	Plexus venosus vesicalis
⑥	Venae rectales mediae (plexus venosus rectalis) (also venae rectales superior and inferiores, not shown)
⑦	Vena pudenda interna
⑧	Venae gluteae inferiores
⑨	Plexus venosus prostaticus
⑩	Plexus venosi uterinus and vaginalis

The male pelvis also contains veins draining the penis and scrotum.

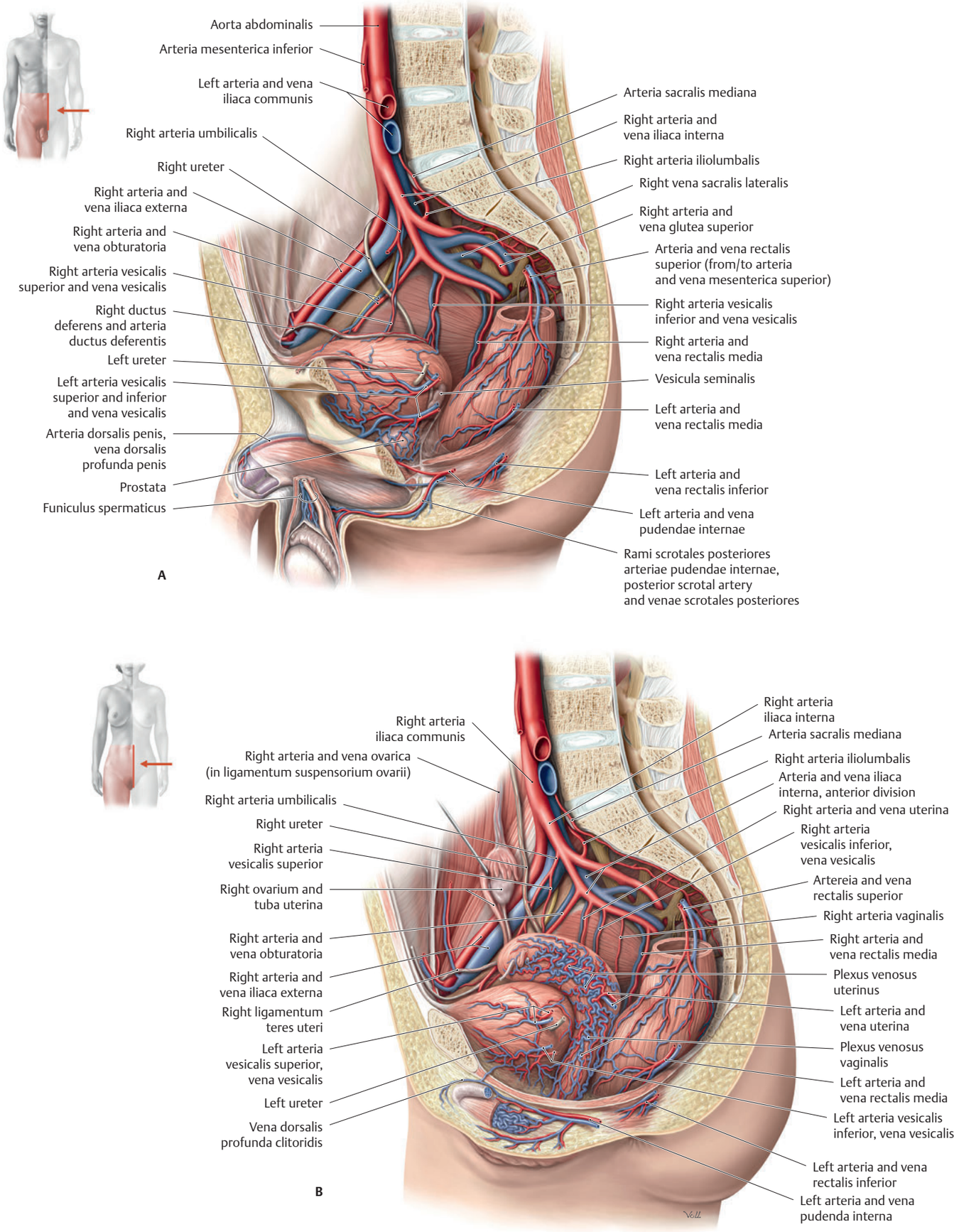


Fig. 15.115 **Blood vessels of the pelvis**
Idealized right hemipelvis, left lateral view. **A** Male pelvis. **B** Female pelvis.

Appendices

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General Principles of Local Anesthesia

Physiology of Peripheral Nerve Depolarization

When a nerve is inactive (not generating action potentials), there is a potential difference across its membrane, which is known as the resting membrane potential (RMP) and is measured in millivolts (mV). Nerve cells have an RMP of −70 mV, which is established by differences in potassium and sodium ion concentrations across the resting cell membrane — high potassium concentration intracellularly and high sodium ion concentration extracellularly. At rest, the nerve cell is relatively resistant to ion passage, but on excitation, voltage-gated sodium channels open, and there is a slow influx of sodium ions into the cell. When a threshold potential is reached, depolarization occurs, and there is a fast influx of sodium ions into the cell, causing the potential across the membrane to become positive (+40mV). The sodium channels quickly close again, preventing further sodium influx. At the same time, potassium channels open, and there is potassium efflux from the cell. This causes repolarization of the cell membrane back to the RMP.

The depolarization of a nerve cell initiates a sequential series of depolarizations along the nerve fiber, thus propagating the impulse (action potential) along the fiber. In myelinated nerve fibers, the depolarizations "jump" from one node of Ranvier to the next (saltatory conduction). In unmyelinated fibers (which do not have nodes of Ranvier), the depolarization spreads to adjacent cells.

Mechanism of Action of Local Anesthetics

Local anesthetics block the inner (cytoplasmic) gate of sodium channels in nerve cells, preventing sodium influx and action potential initiation and propagation. Termination of action of the anesthetic at the site of injection is by diffusion of the active drug into the systemic circulation, followed by metabolism and elimination.

Duration of Anesthesia

Duration of dental local anesthesia can be defined in terms of duration of pulpal anesthesia versus the duration of soft tissue anesthesia. Usually, dentists try to maximize the duration of pulpal anesthesia and minimize the undesirable persistence of soft tissue anesthesia. The duration of pulpal anesthesia and the duration of soft tissue anesthesia of some of the main local anesthetic agents following maxillary infiltration and an inferior alveolar nerve block are listed in **Table A.1**.

General Injection Technique

The fingers of the supporting hand retract the soft tissue around the injection site, enabling the dentist to visualize the target area. These fingers may also be used to provide stability for the syringe and can act as reference points for some injections.

When ready to inject, the needle is inserted gently and directly in one continuous movement to the target area. The dentist should then aspirate to ensure that the tip of the needle does not lie within a blood vessel. Most dental syringes are "self-aspirating," meaning that if the plunger of the syringe is slightly deployed, it bounces back, aspirating (sucking) as it does so. If the syringe is not self-aspirating, aspiration is performed by drawing back slightly on the plunger. The absence of blood in the local anesthetic cartridge suggests that no vessel has been breached. If there is blood in the cartridge, the needle tip should be repositioned slightly and aspiration repeated. Following a negative aspiration result, the local anesthetic is injected slowly, exerting as little pressure as possible. Injection into the palatum durum and interdental papillae are exceptions because the tunica mucosa is tightly adherent to the supporting periosteum in these areas, necessitating that some pressure is used.

Classification of Injection Techniques

Infiltration

Local anesthetic solution is deposited at the level of the tooth apices and diffuses through alveolar bone to bathe the periapical nerves.

Nerve Blocks

Local anesthetic solution is deposited around the main nerve trunk and therefore anesthetizes all of the branches distal to this.

Table A.1 **Duration of anesthesia with some local anesthetic agents**

Local anesthetic agent	Maxillary infiltration		Inferior alveolar nerve block	
	Duration of pulpal anesthesia (min)	Duration of soft tissue anesthesia (min)	Duration of pulpal anesthesia (min)	Duration of soft tissue anesthesia (min)
Lidocaine 2% with 1:100,000 epinephrine*	45–60	170	85	190
Articaine 4% with 1:100,000 epinephrine*	45–60	190	90	230
Bupivacaine 0.5% with 1:200,000 epinephrine*	90	340	240	440
Prilocaine 4% plain	20	105	55	190
Mepivacaine 3% plain	25	90	40	165

* The duration of action is prolonged when combined with epinephrine, a vasoconstrictor. A "plain" solution contains no vasoconstrictive agent.

Overview of Nerves Anesthetized

Injections given within the cavitas oris anesthetize a branch or branches of either the nervus maxillaris or nervus mandibularis division of the nervus trigeminus (CN V_2 or CN V_3, respectively) on the same side as the injection (**Figs. A.1** and **A.2**).

Failure of Anesthesia

Patient Variation

A typical dose of local anesthetic profoundly anesthetizes some patients and may not sufficiently anesthetize others. The dentist must try to ascertain whether failure is due to patient variation or improper injection technique. If due to the former, then more local anesthetic may be given to achieve adequate anesthesia. Likewise, differences occur between patients in the duration of action of anesthetics. The best way to mitigate these differences is to begin treatment as soon as anesthesia is achieved: ~2 minutes after injection for an infiltration and ~5 minutes after injection for a block.

Acute Pulpitis or Apical Abscess

Acute pulpitis (pulpal inflammation) results in a hyperemic tooth (a tooth in which the pulpal blood vessels dilate causing a painful increase in pressure) that is difficult to adequately anesthetize. The pus of an apical abscess can prevent proper diffusion of the local anesthetic solution to the periapical nerves and vessels.

Intravascular Injection

If all or part of an injection of local anesthetic is deposited intravascularly, then there may be little or no anesthesia achieved.

Injection into Muscles or Their Fascia

If the local anesthetic is deposited in a muscle or its fascia instead of into the bone near the teeth apices, then the distance the anesthetic has to diffuse to reach the apical nerves and vessels is increased, resulting in reduced anesthesia. Injection into a muscle can also produce trismus (restricted mouth opening).

Complications and Their Treatment

Fainting

This is the most common systemic complication and is likely attributed to anxiety over the procedure. It can be minimized by administering local anesthetic with the patient supine. If fainting does occur, place the patient in a supine position, and recovery will occur rapidly.

Allergic Reactions

Allergy to local anesthetic is uncommon but possible. It may be due to allergy to the drug, allergy to the additives for compounding the drug, or latex allergy to the rubber bung located at one end of a local anesthetic cartridge. Allergy manifests as facial flushing, swelling, rash, itching, and wheezing. The patient should be sent for allergy testing to determine the precise cause. For minor allergic reactions, provide reassurance, and antihistamines if necessary. For severe (anaphylactic) reactions, urgently call for an ambulance, place the patient in a supine position, and give emergency medication as needed (e.g., intramuscular epinephrine, intravenous hydrocortisone, and oxygen by mask).

Cardiovascular Collapse

Cardiovascular collapse may be precipitated by, or exacerbated by stress, excessive amounts of local anesthetic, and improper aspiration, leading to deposition of local anesthetic in a blood vessel. Epinephrine in the local anesthetic can act directly on the heart, which, if previously diseased, can cause arrhythmias.

If this occurs, urgently call for an ambulance, place the patient in a supine position, and maintain airway and circulation.

Hematomas

Small hematomas are of little consequence. Larger hematomas can compromise the airway.

No treatment is needed for small hematomas; large hematomas due to arterial bleeding, if they are not self-limiting, may require ligation of the vessel.

Trismus

Trismus is the inability to open the mouth normally. It usually occurs after an nervus alveolaris inferior block that is given too low, resulting in hematoma formation in the musculus pterygoideus medialis. This may be accompanied by infection.

Treatment includes reassurance, antibiotics, and encouragement to progressively try to open the mouth.

Facial Paralysis

Facial paralysis (or palsy) may occur following an improperly placed nervus alveolaris inferior block. If the needle is directed too far posteriorly, the tip may enter the lamina superficialis of fascia cervicalis that surrounds the glandula parotidea. Local anesthetic is therefore able to penetrate the gland and anesthetize the five branches of the nervus facialis that are embedded within it. This is manifested by the patient's inability to frown or blink and drooping of the mouth on the affected side. The facial paralysis is transient, normally lasting for ~1 hour.

Treatment includes reassurance and a protective eye covering until the blink reflex returns.

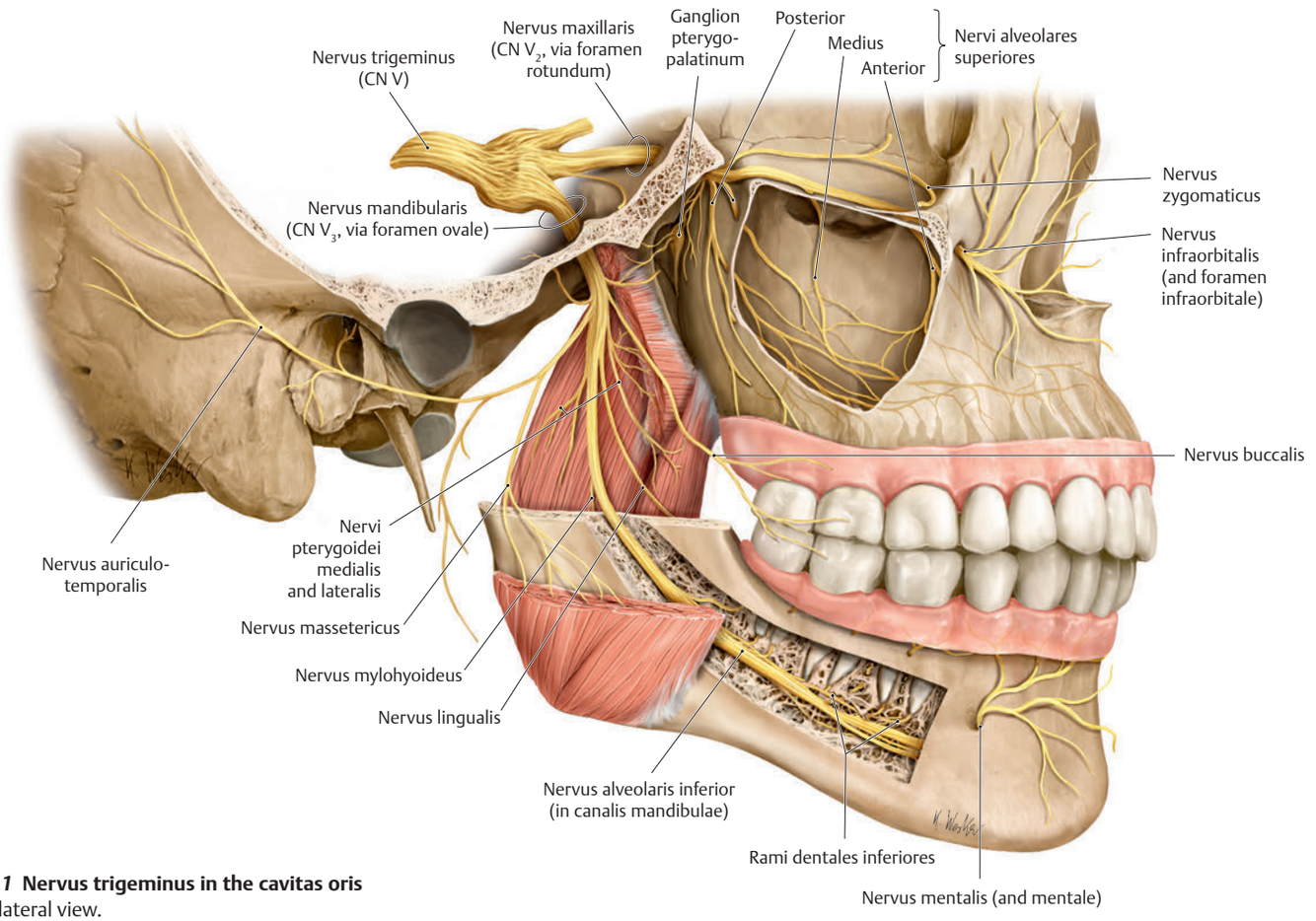


Fig. A.1 **Nervus trigeminus in the cavitas oris**
Right lateral view.

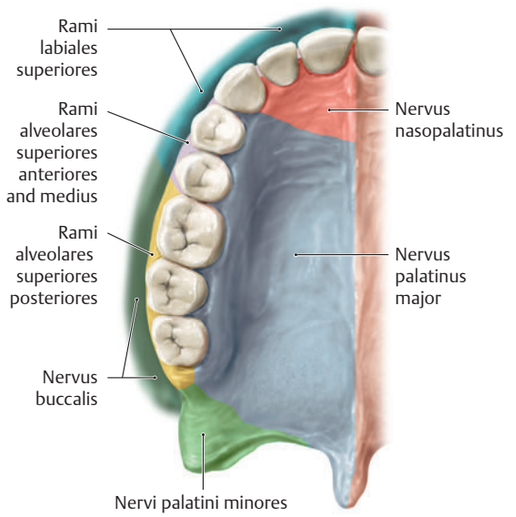


Fig. A.2 **Innervation of the palatum durum**
Inferior view.

Maxillary Anesthesia

Dentes Incisivi and Canini Maxillares

Anatomy

The dentes incisivi and canini maxillares and their associated periodontal ligaments, buccal gingiva, mucosa, and supporting bone are innervated by the rami alveolares superiores anteriores, which branch off the nervus infraorbitalis just before it emerges from the foramen infraorbitale (**Table A.2**). These nerves anastomose over the midline. The palatal gingiva, mucosa, and supporting bone are innervated by the nervus nasopalatinus, which emerges through the foramen incisivum.

The medial spread of local anesthetic may be hindered by the frenulum labii superioris that anchors the lip to the attached gingiva in the midline.

The maxilla has a thin, porous lamina (layer) easily penetrated by an infiltration of local anesthetic solution.

Injection Technique

- Insert the needle in the mucobuccal fold immediately superior to the crown of the tooth being anesthetized and pass it axially toward the apex of the tooth (**Fig. A.3A** and **B**). The needle should be in close proximity to the bone to ensure that the local anesthetic solution has minimal diffusion distance before it bathes the periapical nerves and vessels.
- Following a negative aspiration result, slowly inject 1.0 to 1.8 mL of local anesthetic.
- For dentes incisivi mediales, the injection is best placed distally due to the close proximity of the spina nasalis anterior.

Clinical Considerations

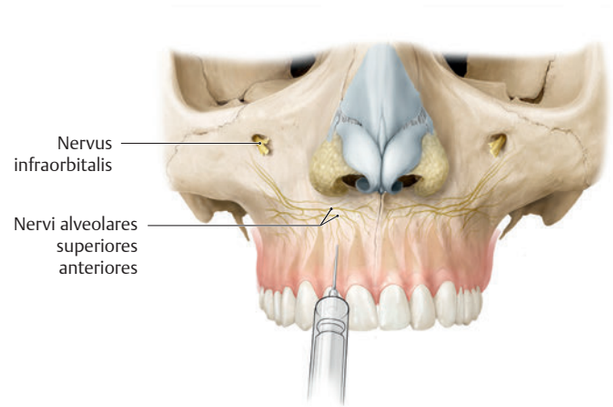
- A mucobuccal fold infiltration is sufficient for cavity preparation and pulpal procedures.
- Extractions will require supplementary anesthesia of the palatal gingiva, mucosa, and supporting bone, either by local infiltration of the palatum (p. 480) or by a nasopalatine block (p. 479).
- Painful injection

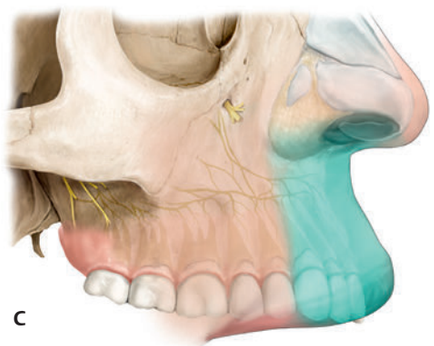
Table A.2 **Anesthesia of dentes incisivi and canini maxillares**

Areas anesthetized* (see Fig. A.3C and D)	Nervus (Fig. A.3B)
Dens incisivus medialis, lateralis* and canini maxillares** and their associated periodontal ligaments, buccal gingiva, mucosa, and supporting bone	Ramus alveolaris superior anterior
Lateral aspect of the nose	Ramus nasalis externus fibers of the nervus infraorbitalis
Upper lip	Ramus labialis superior fibers of the nervus infraorbitalis

* This applies when the injection is placed superior to the dens incisivus lateralis maxillaris.
** The root of the dens caninus is longer, and the apical part of the root is often distally oriented; therefore, the dens caninus maxillaris dexter may not be sufficiently anesthetized for cavity preparation from this injection alone.

A





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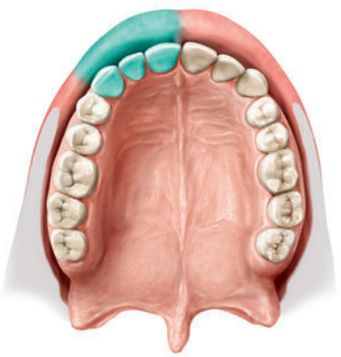

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Fig. A.3 **Infiltration of the maxillary lateral incisor**
A Injection technique.
B Nerves anesthetized, anterior view.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view. Note the lips roughly extend to the first premolar region on each side; the cheeks are colored gray.

Nervus Infraorbitalis Block

Anatomy

The nervus infraorbitalis is a continuation of the nervus maxillaris as it enters the canalis infraorbitalis. The ramus alveolaris superior anterior and ramus alveolaris superior medius (when present) branch from this nerve just before it exits the canalis infraorbitalis and are therefore also anesthetized by diffusion of local anesthetic from the injection site (**Table A.3**).

Injection Technique

- Palpate the center of the inferior margin of the orbit with the index finger of the supporting hand. At a point ~1 cm below the margo infraorbitalis, the foramen infraorbitale can be palpated. Hold the index finger at that point, while retracting the upper lip with the thumb of the supporting hand. Insert the needle at the mucobuccal fold immediately superior to the 1st maxillary premolar, parallel to the long axis of the tooth, toward the tip of the index finger (**Fig. A.4A** and **B**).
- Following a negative aspiration result, slowly inject ~1 mL of local anesthetic.

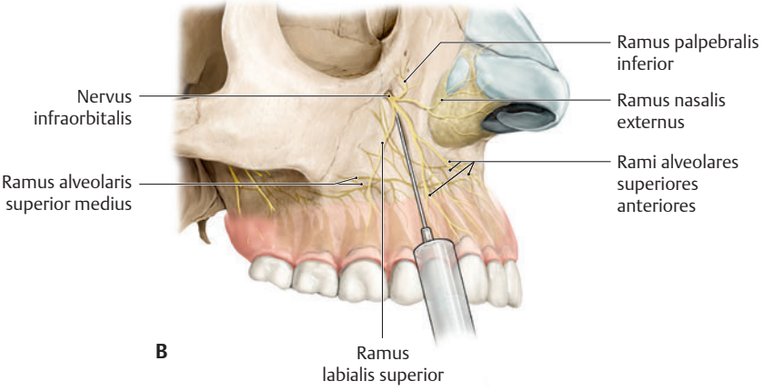
Clinical Considerations

- To avoid having to give more than one injection, an infraorbital block may be used to anesthetize multiple teeth for cavity preparation or pulpal procedures. It may also be used when infiltration has failed to achieve pulpal anesthesia or is contraindicated (e.g., infiltration would require an injection into an infected area).
- Extractions of any of the teeth anesthetized by an infraorbital block will require supplementary anesthesia of the palatal gingiva by a nervus nasopalatinus or nervus palatinus major block or by local infiltration of the palatum.
- Hematoma is rare with this injection, but there is potential for iatrogenic (accidental, clinician-induced) damage to the patient's eye.
- To obtain complete anesthesia of the dens incisivus medialis on the same side as the injection, it may be necessary to block anastomosing fibers from the ramus alveolaris superior anterior on the contralateral side of the midline. This is achieved by placing a supplemental 0.5 mL of local anesthetic in the contralateral buccal fold, just distal to the central incisor.

Table A.3 **Anesthesia following a nervus infraorbitalis block**

Areas anesthetized (Fig. A.4C and D)	Nervus (Fig. A.4B)
Dentes incisivi and caninus and their associated periodontal ligament, buccal gingival, mucosa, and supporting bone	Ramus alveolaris superior anterior
Dentes premolares and possibly the cuspis mesiobuccalis of the dens molaris primus and their associated periodontal ligament, buccal gingival, mucosa, and supporting bone	Ramus alveolaris superior medius or fibers from the plexus dentalis superior
Lateral aspect of the nose	Rami nasales externi of the nervus infraorbitalis
Lower eyelid	rami palpebrales inferiores of the nervus infraorbitalis
Upper lip and mucosa	Rami labiales superiores of the nervus infraorbitalis

A



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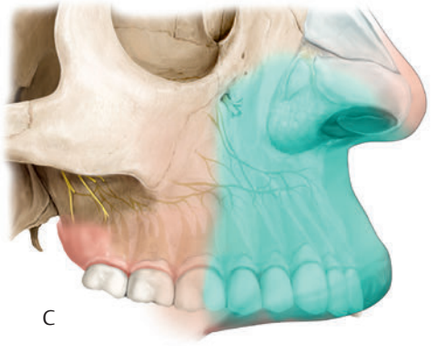

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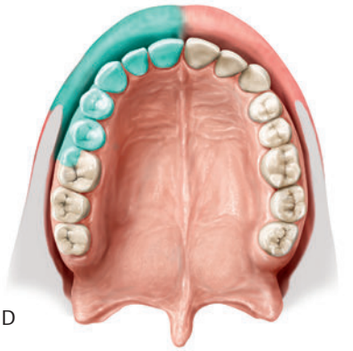

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Fig. A.4 **Nervus infraorbitalis block**
A Injection technique.
B Nerves anesthetized, right lateral view.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view.

Dentes Premolares Maxillares

Anatomy

The premolar area is innervated by the plexus dentalis superior, which is formed by convergent branches from the rami alveolares superiores posteriores and the rami alveolares superiores anteriores. Sometimes there is a ramus alveolaris superior medius that, when present, innervates the dentes premolares, their periodontal ligaments, buccal gingiva, and supporting bone, and often the radix mesiobuccalis of the dens molaris primus (**Table A.4**). The palatal gingiva, mucosa, and supporting bone adjacent to the dentes premolares is mainly innervated by the nervus palatinus major, but the area of the first dens premolaris may also be innervated by fibers of the nervus nasopalatinus.

Diffusion of local anesthetic deposited in the mucobuccal fold is especially good in this area because the bone lamina is thin, and the apices of the premolars lie very close to the lamina. Consequently, small volumes of local anesthetic are required, and the radices palatales of the dentes premolares are almost always anesthetized by this one injection.

Injection Technique

The same infiltration technique is used as for the dentes incisivi and canini. Deposit 1.0 to 1.5 mL of local anesthetic solution around the apex of the premolars (**Fig. A.5A** and **B**).

Clinical Considerations

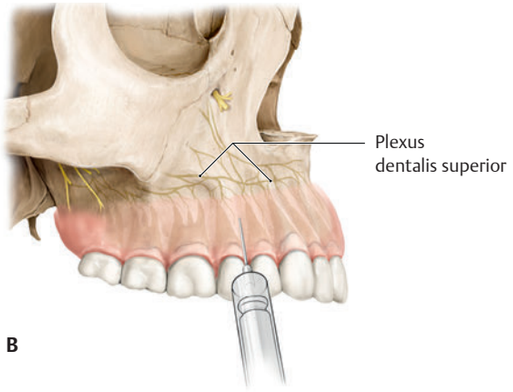
- A mucobuccal fold infiltration is sufficient for cavity preparation and pulpal procedures.
- Extractions will require supplementary anesthesia of the palatal gingiva, mucosa, and supporting bone, usually by one local infiltration injection of the palatum between the dentes premolares.

Table A.4 **Anesthesia of dentes premolares maxillares**

Area anesthetized* (Figs. A.5C and D)	Nervus (Fig. A.5B)
Both dentes premolares maxillares* and their associated periodontal ligaments, buccal gingival, mucosa, and supporting bone	Ramus alveolaris superior medius or branches of the plexus dentalis superior
Dens caninus and the cuspis mesiobuccalis of the dens molaris primus** and their associated periodontal ligaments, buccal gingival, mucosa, and supporting bone	

* This applies when the injection is placed between the dentes premolares.
** These teeth, soft tissues, and bone may also be anesthetized to a lesser extent.

A



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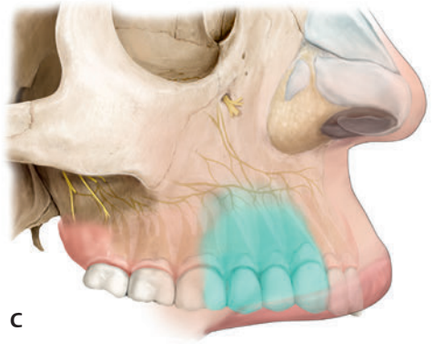

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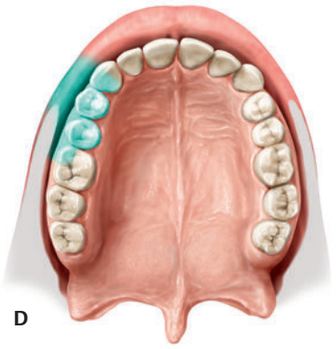

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Fig. A.5 **Infiltration of the maxillary premolars**
A Injection technique.
B Nerves anesthetized, right lateral view.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view.

Dentes Molares Maxillares

Anatomy

The molar region of the maxilla is innervated by the ramus alveolaris superior posterior, which branches from the nervus infraorbitalis before it enters the canalis infraorbitalis. These branches enter foramina on the facies infratemporalis of the maxilla, where they enter to innervate the dentes molares maxillares and their associated periodontal ligaments, buccal gingiva, mucosa, and supporting bone (**Table A.5**). The distance between the mucobuccal fold and the apices of the dentes molares maxillares varies from patient to patient. This distance may be increased by the lower margin of the arcus zygomaticus or when the sinus maxillaris extends down between the buccal and palatal roots. This can lead to failure of a buccal infiltration injection.

Injection Technique

- The same infiltration technique as for dentes incisivi and canini is used. Introduce the needle to the mucobuccal fold slightly mesially to the dens molaris primus maxillaris (**Fig. A.6A** and **B**). A second injection may be given in the mucobuccal fold at the distal aspect of the dens molaris primus maxillaris to ensure the tooth is adequately anesthetized.
- Following a negative aspiration result, slowly inject 1.0 to 1.8 mL of local anesthetic.

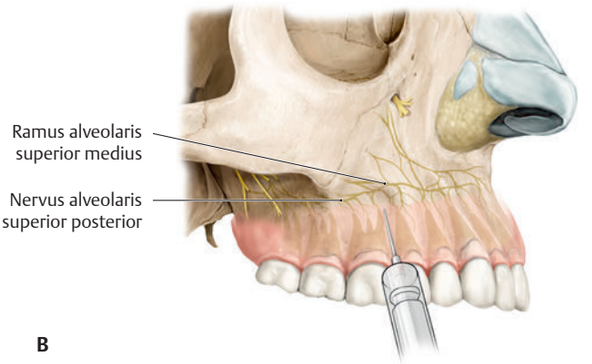
Clinical Considerations

- A mucobuccal fold infiltration injected is usually sufficient for cavity preparation and pulpal procedures. Rarely, it may be necessary to perform a palatal injection to achieve complete anesthesia of the radix palatinalis.
- Extractions will require supplementary anesthesia of the palatal gingiva, mucosa, and supporting bone by nervus palatinus major block or by local infiltration.
- For infiltration injections of the dentes molares tertii, the patient should not be asked to open too widely; otherwise, the processus coronoideus of the mandibula is moved anteriorly and can cover the injection site.

Table A.5 **Anesthesia of dentes molares maxillares**

Area anesthetized* (Fig. A.6C and D)	**Nervus (Fig. A.6B)**
Cuspis mesiobuccalis of the dens molaris primus	Ramus alveolaris superior medius (if present)
Dentes molares primus and secundus* and their associated periodontal ligaments, buccal gingiva, mucosa, and supporting bone	Rami alveolares superiores posteriores
Lateral aspect of the lip (may be very slight or absent)	Ramii labiales superiores of the nervus infraorbitalis
* This applies when injection is placed mesially and distally to the 1st molar.	

A



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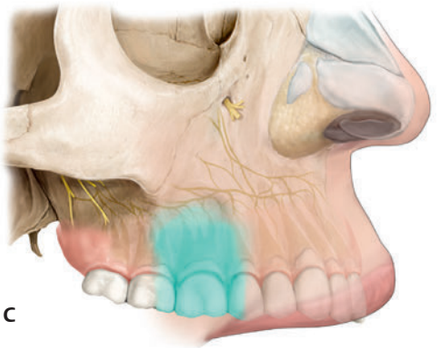

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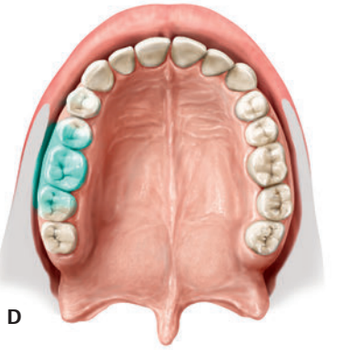


D

Fig. A.6 **Infiltration of the maxillary molars**
A Injection technique.
B Nerves anesthetized, right lateral view.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view.

Ramus Alveolaris Superior Posterior Block

Anatomy

The ramus alveolaris superior posterior is located in the fossa infratemporalis and lies in close proximity to the plexus pterygoideus (**Table A.6**).

Injection Technique

- Instruct the patient to open his or her mouth and swing the mandibula toward the same side to allow better visualization of the injection site and more room to maneuver.
- Insert the needle into the mucobuccal fold just superior to the dens molaris secundus maxillaris, between the medial border of the ramus mandibulae and the tuber maxillae. Then advance the needle inward, backward, and upward 1.5 to 2.0 cm (**Fig. A.7A** and **B**).
- Following a negative aspiration result, slowly deposit 1.0 to 1.8 mL of local anesthetic .

Clinical Considerations

- This injection is sufficient for cavity preparation and pulpal procedures on all of the dentes molares maxillares.
- Extractions will require supplementary anesthesia of the palatal gingiva, mucosa, and supporting bone by a nervus palatinus major block or by local infiltration.

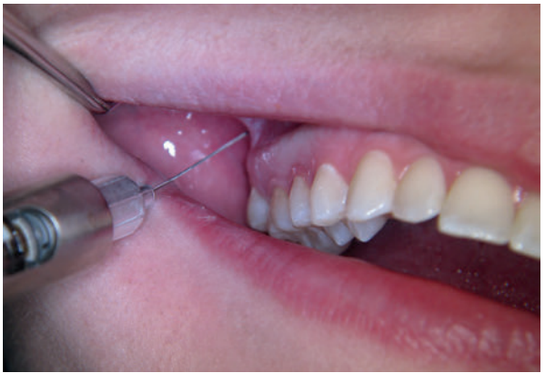
Notes

There is a significant risk of hematoma by introduction of the needle into the plexus pterygoideus. Short needles and careful aspiration reduce this risk.

Table A.6 **Anesthesia following a ramus alveolaris superior posterior block**

Areas anesthetized* (Fig. A.7C and D)	Nervus (Fig. A.7B)
Dentes molares maxillares primus,* secundus, and tertius and their associated periodontal ligaments, buccal gingival, mucosa, and supporting bone	Rami alveolares superiores posteriores

* The radix mesiobuccalis of the dens molaris primus may not be anesthetized and may therefore require supplemental buccal infiltration anesthesia mesial to the dens molaris primus (to anesthetize the ramus alveolaris superior medius).



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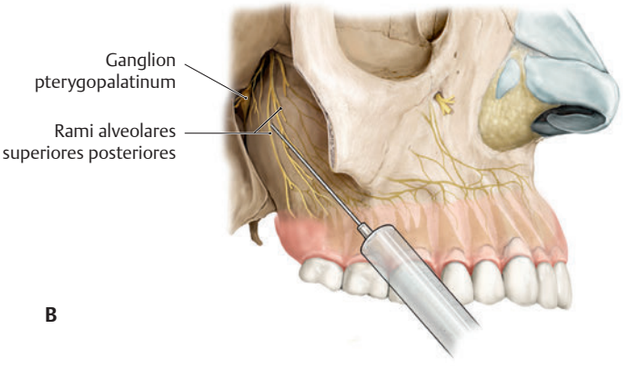

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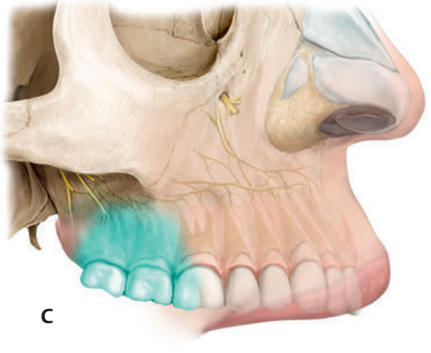

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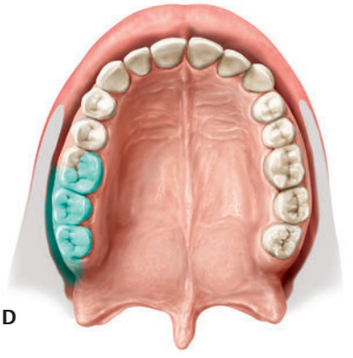


D

Fig. A.7 **Ramus alveolaris superior posterior block**
A Injection technique.
B Nerves anesthetized, right lateral view.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view.

Nervus Maxillaris Division Block

Anatomy

The nervus maxillaris division block is an advanced local anesthetic technique. It uses the canalis palatinus major to reach the fossa pterygopalatina and therefore enables the dentist to anesthetize all branches of the nervus maxillaris (**Table A.7**). The canal is usually vertical, thus aiding this procedure.

Injection Technique

- Locate the foramen palatinum majus with a cotton swab applicator, which can be felt to sink slightly into the foramen. Inject a small amount of anesthetic. This lessens patient's discomfort for the next part of the procedure.
- Insert the needle into the foramen palatinum majus ~28 to 30 mm. The needle tip should now be located in the fossa pterygopalatina (**Fig. A.8A** and **B**).
- Following a negative aspiration result, slowly inject 1 to 2 mL of local anesthetic.

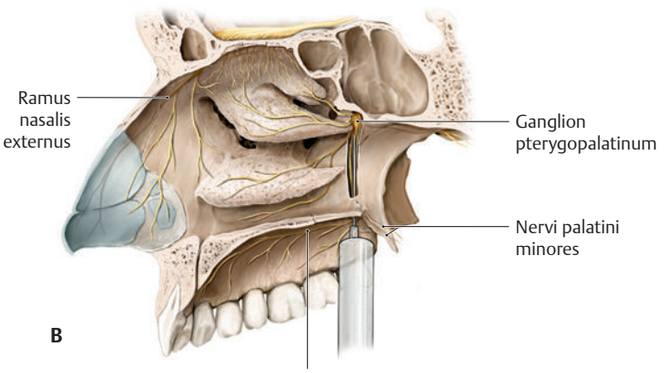
Clinical Considerations

- This injection is useful when extensive restorative dentistry and surgical procedures are needed.
- The needle should never be forced into the foramen palatinum majus to avoid fracture of the wall of the canalis palatinus major.
- If the needle is placed too far superiorly, the anesthetic can be deposited in the eye, affecting vision.
- Hematoma formation may occur due to rupture of the vessels that also run in the canalis palatinus major.

Table A.7 **Anesthesia following a nervus maxillaris division block**

Areas anesthetized (Fig. A.8C and D)	Nervus (Fig. A.8B)
All maxillary teeth and their associated periodontal ligaments, buccal gingiva, mucosa, and supporting bone	Rami alveolares posteriores anteriores, medius (if present), and posteriores
All palatal gingival, mucosa, and supporting bone	Nervus nasopalatinus (anterior one-third) and nervus palatinus major (posterior two-thirds)
Lateral aspect of the nose	Rami nasales externi of the nervus infraorbitalis
Lower eyelid	Rami palpebrales inferiores of the nervus infraorbitalis
Upper lip	Rami labiales superiores of the nervus infraorbitalis

A



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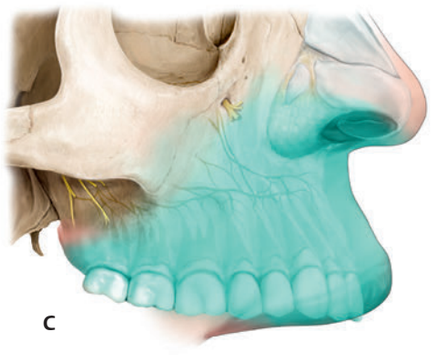

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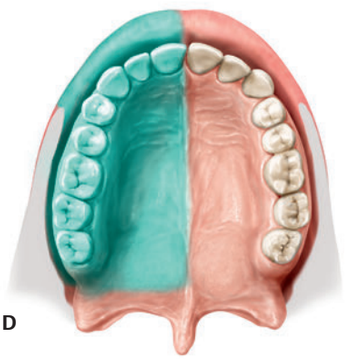


D

Fig. A.8 **Maxillary division block**
A Injection technique, inferior view.
B Nerves anesthetized, left lateral view of the right lateral nasal wall with the ganglion pterygopalatinum exposed.
C Areas anesthetized, right lateral view.
D Areas anesthetized, inferior view.

Nervus nasopalatinus Block

Anatomy

The nervus nasopalatinus is a branch of the nervus maxillaris that passes through the ganglion pterygopalatinum (**Table A.8**). It enters the cavitas nasi through the foramen sphenopalatinum, passes across the roof of the cavitas nasi, then runs obliquely downward and forward in the septum nasi between the supporting bone and mucous membrane. It descends farther through the canalis incisivus and emerges into the anterior palatum durum through the foramen incisivum. Branches of the nervus nasopalatinus anastomose with branches of the contralateral nervus nasopalatinus and with the nervus palatinus major. Because the right and left nervi nasopalatini exit the foramen incisivum in close proximity, one injection anesthetizes both sides of the anterior one third of the palatum durum.

Injection Technique

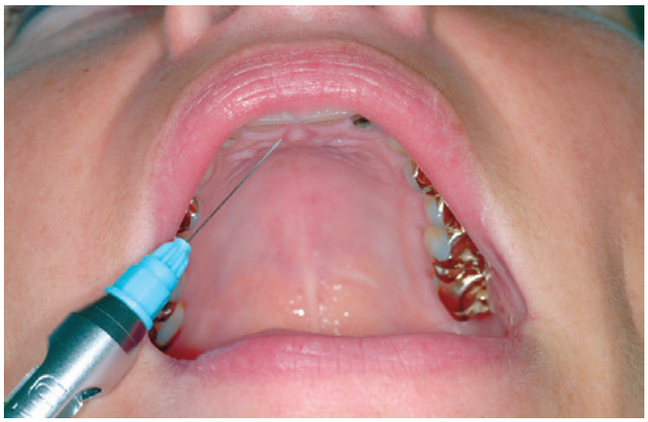
- Using a cotton swab applicator, apply pressure close to the injection site to reduce the perception of pain. Insert the needle into the palatal mucosa lateral to the papilla incisiva until bone is contacted (**Fig. A.9A** and **B**).
- After withdrawing the needle slightly and following a negative aspiration result, inject a very small volume of local anesthetic under minimal pressure. The tissue will be seen to blanch due to the vasoconstrictor in the local anesthetic solution.

Clinical Considerations

- This injection is used to supplement buccal infiltration injections for extraction of any of the maxillary anterior teeth.
- This injection is widely perceived to be the most painful variety of dental injection. It is particularly painful because the mucosa of the palatum durum is tightly bound to the periosteum of the palatum, allowing little space for the diffusion of local anesthetic.

Table A.8 **Anesthesia following a nervus nasopalatinus block**

Area anesthetized (Fig. A.9C)	Nerve (Fig. A.9B)
The maxillary gingiva, mucosa, and supporting bone from the right dens caninus maxillaris to the left dens caninus maxillaris	Nervus nasopalatinus



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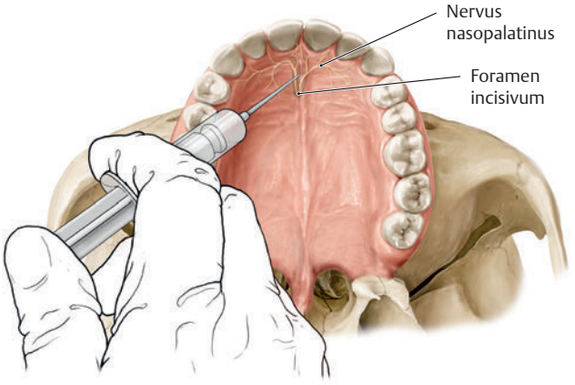

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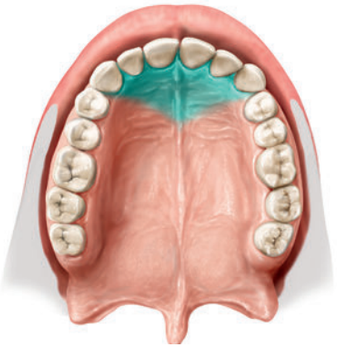


C

Fig. A.9 **Nervus nasopalatinus block**
A Injection technique, inferior view.
B Nerves anesthetized, inferior view.
C Areas anesthetized, inferior view.

Nervus Palatinus Major Block

Anatomy

The nervus palatinus major is a branch of the nervus maxillaris that passes through the ganglion pterygopalatinum (**Table A.9**). It runs from the fossa pterygopalatina, down through the canalis palatinus major, and through the foramen palatinum majus to reach the palatum durum. It then runs forward in a groove to a point just distal to the dentes canini.

Injection Technique

- The foramen palatinum majus lies ~0.5 to 1.0 cm mesial to the margin of the gingiva at the distal border of the dens molaris secundus maxillaris (**Fig. A.10A** and **B**). It should be located by using a cotton swab applicator, which can be felt to sink slightly into the foramen. With the cotton swab applicator, apply pressure close to the injection site to reduce the perception of pain. Insert the needle until it contacts bone. Withdraw it slightly, then aspirate.
- Following a negative aspiration result, slowly inject around 0.1 mL of local anesthetic.

Clinical Considerations

- This injection is used to anesthetize palatal tissues for multiple extractions involving the dentes premolares and molares maxillares on one side. It may also be useful for mucogingival surgical procedures.
- Bone contact prior to injection is necessary to ensure that the needle is not in the palatum molle.
- The palatum in the region of the foramen palatinum majus is tightly bound to the supporting bone but less so than at the foramen incisivum. Therefore, although still painful, this injection is less so than for the nervus nasopalatinus block.

Table A.9 Anesthesia following a nervus palatinus major block

Area anesthetized (Fig. A.10C)	Nervus (Fig. A.10B)
The maxillary gingiva, mucosa, and supporting bone from the dens premolaris primus maxillaris to the posterior palatum durum to the midline of the palatum durum	Nervus palatinus major

Supplementary Infiltration of the Palatum

Anatomy

Supplementary infiltration of the palatum may anesthetize fibers of the nervus nasopalatinus and/or nervus palatinus major (depending on the site of the injection) (**Table A.10**).

Injection Technique

- Using a cotton swab applicator, apply pressure close to the injection site to reduce the perception of pain. Insert the needle into the palatal mucosa ~1 cm from the neck of the tooth to be anesthetized, until bone is contacted.
- Withdraw the needle slightly and aspirate.
- Following a negative aspiration result, inject ~0.1 mL of local anesthetic. The mucosa will be seen to blanch due to the vasoconstrictor in the local anesthetic.

Clinical Considerations

- This injection is used to supplement buccal infiltration, infraorbital, or ramus alveolaris superior posterior blocks for extractions of the maxillary teeth. It is more commonly performed than a nervus nasopalatinus or nervus palatinus major block.
- The injection is painful.

Table A.10 Supplementary infiltration of the palatum

Areas anesthetized	Nervus
Palatal gingival, mucosa, and supporting bone in the vicinity of the injection site	Fibers of the nervus nasopalatinus and/or nervus palatinus major

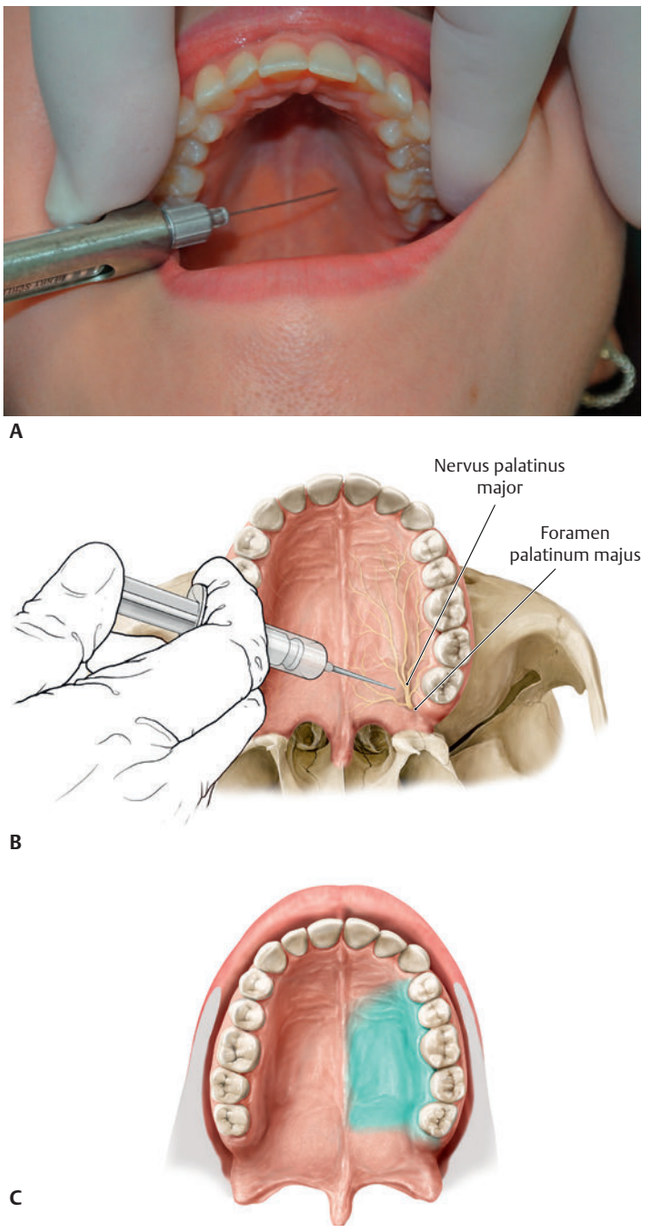


Fig. A.10 **Nervus palatinus major block**
A Injection technique, inferior view.
B Nerves anesthetized, inferior view.
C Areas anesthetized, inferior view.

Mandibular Anesthesia

Dentes Incisivi and Canini Mandibulares

Anatomy

The dentes incisivi and canini are innervated by the nervus incisivus, a terminal branch of the nervus alveolaris inferior (**Table A.11**). Its course lies within bone, but it may be anesthetized by infiltration because the bone lamina in this area of the mandibula is thin and porous. Because the bone around the dentes canini in adults may be denser, infiltration anesthesia may fail. In this case, a nervus mentalis block or nervus alveolaris inferior block can be used to ensure sufficient anesthesia of a dens caninus.

The buccal soft tissues are innervated by the nervus mentalis, while the lingual gingiva and supporting bone are supplied by the nervus sublingualis (a branch of the nervus lingualis).

Injection Technique

The same infiltration technique is used as for the dentes incisivi and canini maxillares. Deposit around 1 mL of local anesthetic around the apices of the teeth (**Fig. A.11A** and **B**, **Table A.11**).

Clinical Considerations

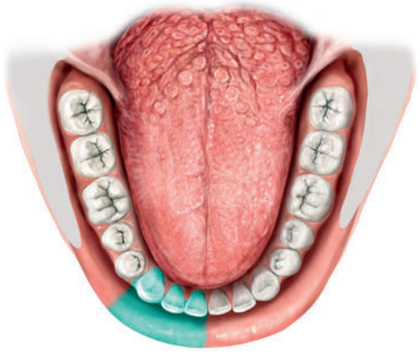
- A mucobuccal fold injection is sufficient for cavity preparation and pulpal procedures of the dentes incisivi mandibulares.
- Extractions require supplemental anesthesia of the lingual gingiva, mucosa, and supporting bone by sublingual infiltration (p. 487).

Table A.11 **Anesthesia of mandibular incisors and canine**

Areas anesthetized* (Fig. A.11C)	Nervus (Fig. A.11B)
Dentes incisivi mandibulares mediales and laterales and dens caninus mandibularis (to a lesser extent)*	Nervus incisivus
Periodontal ligaments, buccal gingiva, mucosa, and supporting bone associated with the incisors	Nervus mentalis
Lower lip	
Chin	

* This applies when the injection is placed at the dens incisivus lateralis mandibularis.

A



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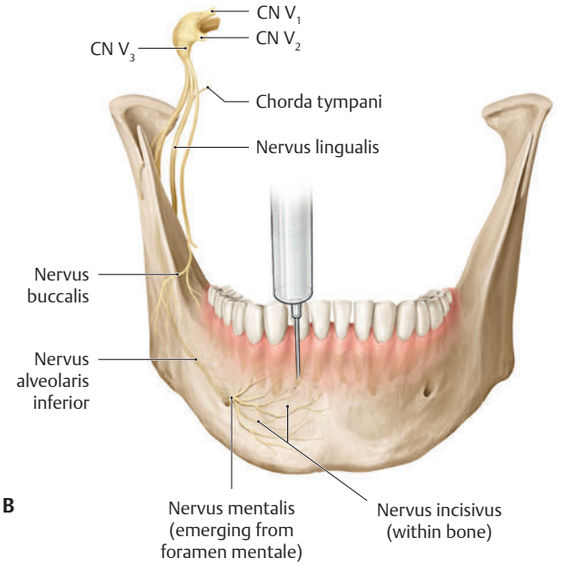


B

Fig. A.11 **Infiltration of the dentes incisivi mandibulares**
A Injection technique, anterior view.
B Nerves anesthetized, anterior view.
C Areas anesthetized, superior view.

Nervus Mentalis Block

Anatomy

The dens premolaris primus mandibularis is innervated by the nervus mentalis in the canalis mandibulae (**Table A.12**). The dens premolaris secundus mandibularis is mainly innervated by the nervus alveolaris inferior. The periodontal ligaments, buccal gingiva, mucosa, and supporting bone in the premolar area are innervated by the nervus mentalis, while the lingual gingiva is supplied by the nervus sublingualis. The foramen mentale lies between and inferior to the apices of the dentes premolares mandibulares.

The thick, substantia compacta in the mandibular premolar region does not normally allow anesthesia of these teeth to be achieved by infiltration anesthesia; therefore, a nervus mentalis block or nervus alveolaris inferior block is used. The exception to this is if articaine is used; in that case, infiltration anesthesia is effective (articaine can achieve anesthesia of all mandibular teeth with the exception of the dentes molares secundus and tertius).

The anatomic direction of the canal that allows passage of the mental nerve is medial→anterior→caudal. The needle should not be oriented in this direction to prevent damage to the nervus mentalis and vessels within the canal.

Table A.12 **Anesthesia following a nervus mentalis block**

Areas anesthetized* (Fig. A.12C)	Nervus (Fig. A.12B)
Dens premolaris primus mandibularis	Nervus mentalis
Dens premolaris secundus mandibularis*	Nervus alveolaris inferior and perhaps some fibers from the nervus mentalis
Dentes caninus,incisivus lateralis, and incisivus medialis	Nervus incisivus**
All periodontal ligaments, buccal gingiva, mucosa, and supporting bone from the dens premolaris secundus to the dens incisivus medialis	Nervus mentalis
Lower lip and chin	Nervus mentalis

* Unreliably anesthetized, as sufficient anesthetic has to diffuse through the foramen mentale and spread distally to anesthetize fibers of the nervus alveolaris inferior, which innervates this tooth.
** The nervus incisivus is incidentally anesthetized by diffusion of local anesthetic during this block.

Injection Technique

- Locate the foramen mentale by palpation or by referring to a radiograph.
- Insert the needle into the mucobuccal fold between the dentes premolares primus and secundus mandibulares.
- Advance the needle until it is at the level of the foramen mentale (**Fig. A.12A** and **B**).
- Following a negative aspiration result, slowly inject 1.0 to 1.5 mL of local anesthetic.

Clinical Considerations

- This injection is sufficient for cavity preparation and pulpal procedures on the dens premolaris primus mandibularis. Cavity preparation may be able to be performed on the dens premolaris secundus mandibularis if anesthesia permits, but pulpal procedures and extensive cavity preparations are likely to require a nervus alveolaris inferiorblock to be performed for adequate anesthesia.
- For extractions of the dens premolaris primus mandibularis, a supplementary nervus sublingualis infiltration is required. For extractions of the dens premolaris secundus mandibularis, a nervus alveolaris inferior is performed during which the nervus lingualis is concurrently blocked.

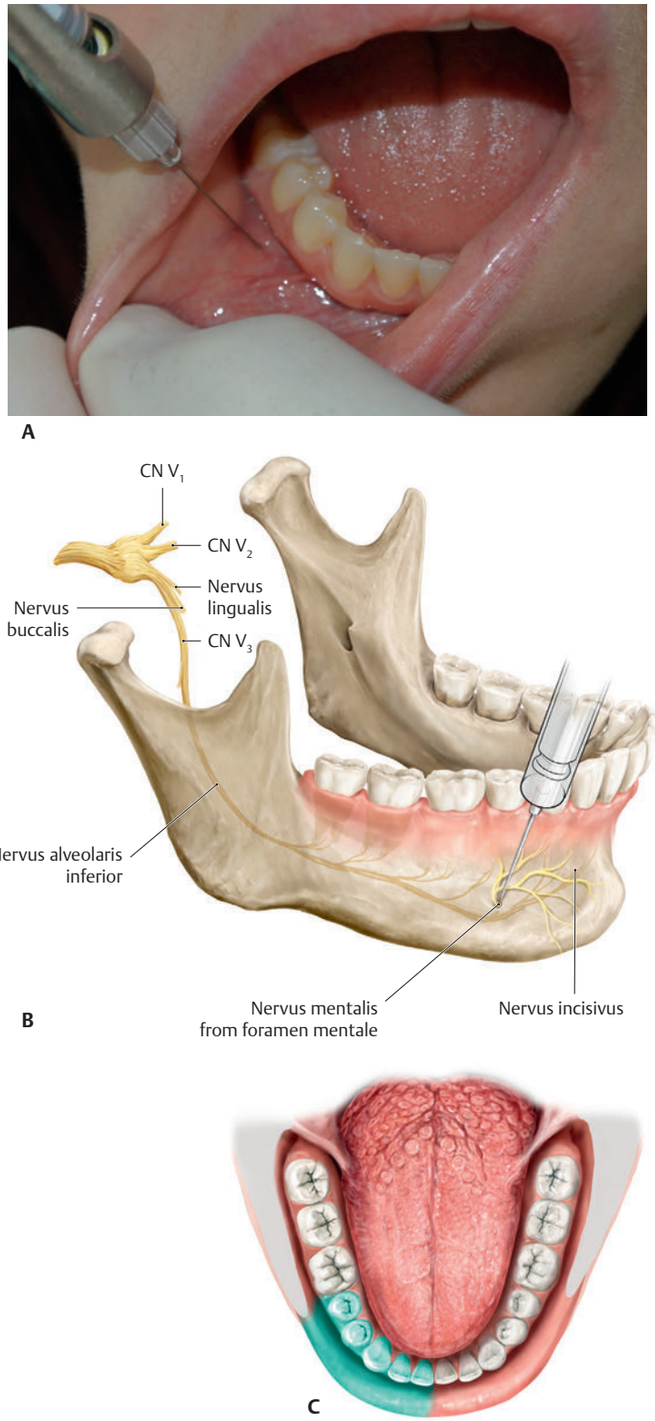


Fig. A.12 **Nervus mentalis block**
A Injection technique.
B Nerves anesthetized, right lateral view.
C Areas anesthetized, superior view.

Nervus Alveolaris Inferior Block

Anatomy

All mandibular teeth are innervated by the nervus alveolaris inferior (and its branches), which runs in the canalis mandibulae (**Table A.13**).

The thick, substantia compacta in the mandibular molar region often does not allow for infiltration anesthesia. Anesthesia of the dentes molares mandibulares therefore requires blockade of the nervus alveolaris inferior before it enters the canalis mandibulae. However, an infiltration injection of articaine has been shown to be effective in anesthetizing all mandibular teeth except the dentes molares secundus and tertius.

Injection Technique

- Instruct the patient to open widely to ensure good visualization of the anatomic landmarks.
- Palpate the coronoid notch of the mandibula with the thumb of the supporting hand.
- The deepest part of the coronoid notch (about halfway up the thumb) generally corresponds to the level of the foramen mandibulae.
- Move the thumb medially to palpate the linea mylohyoidea mandibulae and then the spatium pterygomandibulare, lateral to the raphe pterygomandibularis. The index and middle fingers lie at the ramus and angulus mandibulae to support the mandibula.
- Direct the needle from the contralateral premolar area into the spatium pterygomandibulare at the level of the foramen mandibulae, while keeping the needle parallel to the occlusal plane of the mandibular teeth on the injection side.
- Insert the needle 20 to 25 mm until bone is contacted (**Fig. A.13A** and **B**).
- Withdraw the needle slightly, then aspirate.
- Following a negative aspiration result, slowly inject ~1.5 mL of local anesthetic into the spatium pterygomandibulare.
- The nervus lingualis is concurrently blocked by withdrawing the needle about halfway (corresponding to the approximate level of the crista temporalis), aspirating, and, if negative, slowly injecting the remaining 0.5 mL of local anesthetic.

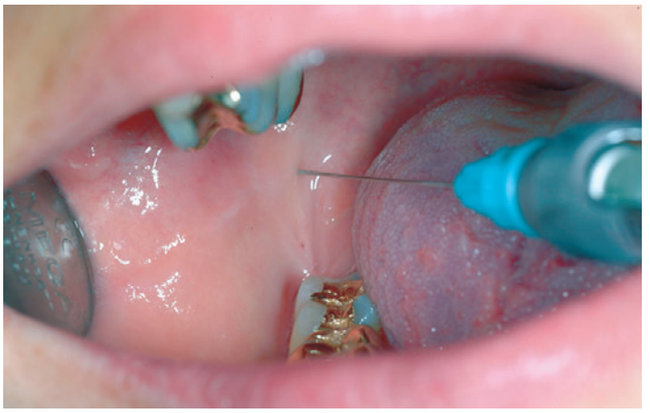
Table A.13 **Anesthesia following a nervus alveolaris inferior block**

Areas anesthetized* (Fig. A.13C and D)	Nervus (Fig. A.13B)
All mandibular teeth	Nervus alveolaris inferior
All buccal gingiva, mucosa, and supporting bone from the dens premolaris secundus to the dens incisivus medialis	Nervus mentalis
Lower lip and chin	Nervus mentalis
All lingual gingiva, mucosa, and supporting bone	Nervus lingualis (molar region) and its nervus sublingualis branch (premolar region to midline)
Anterior two thirds of the tongue	Nervus lingualis

* On the same side as the injection.

Clinical Considerations

- This injection is sufficient for cavity preparations, pulpal procedures, and surgical procedures involving the lingual aspect of the mandibular teeth.
- Extractions of the dentes molares mandibulares require supplemental anesthesia of the nervus buccalis.
- The patient may describe an “electric shock” if the tip of the needle directly touches the nervus alveolaris inferior. In this case, the needle should be withdrawn slightly, as the nerve may be damaged by intraneural injection, and the symptoms are often persistent.
- The foramen mandibulae is not at the same level in all patients; therefore, this technique has to be modified accordingly. In children, it is located closer to the posterior border of the mandibula until more bone is produced. In edentulous patients, alveolar bone resorption has occurred, making the deepest part of the coronoid notch lower than normal. To avoid making the block too low, direct the needle higher than the deepest part of the coronoid notch.
- In class II malocclusion, when the mandibula is hypoplastic (underdeveloped), the foramen mandibulae may be located more inferior than normal.
- In class III malocclusion, when the mandibula is hyperplastic (overdeveloped) the foramen mandibulae may be located more superior than normal.
- The musculus pterygoideus medialis is stretched and tense if the mouth is opened widely and may hinder proper placement of the needle. This can be overcome by slightly reducing mouth opening after the initial insertion of the needle.
- If the needle is angled too far mesially, the bone of the crista temporalis is contacted almost immediately, and the needle should be repositioned laterally. If the needle is inserted too far posteriorly, then the local anesthetic solution may be deposited in the musculus pterygoideus medialis, causing postoperative muscle pain and trismus (muscle spasm). If the needle continues farther posteriorly, then it may penetrate the capsule of the glandula parotidea. If local anesthetic is deposited within the capsule, it causes a transient facial paralysis (Bell’s palsy, see p. 471. Ensuring that the needle contacts bone at the appropriate depth ensures proper placement and mitigates the likelihood of any complications.



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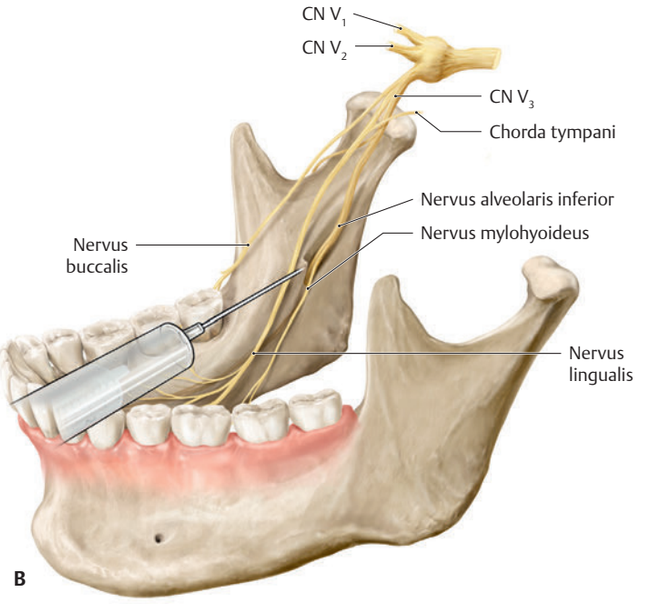

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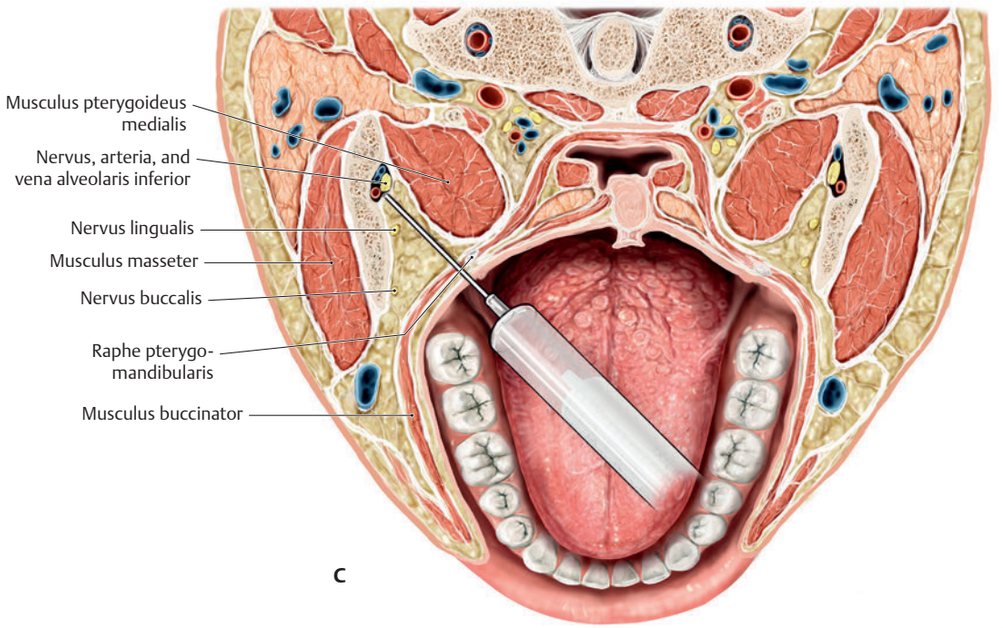

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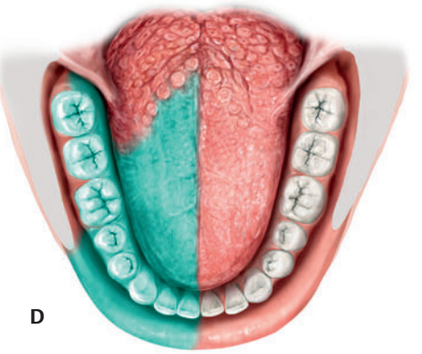


D

Fig. A.13 **Nervus alveolaris inferior block**
A Injection technique.
B Nerves anesthetized, left lateral view.
C Transverse section just above the occlusal plane of the mandibular teeth, superior view.
D Areas anesthetized, superior view.

Gow–Gates Block

Anatomy

This block is a variation of the nervus alveolaris inferior block. The aim is to anesthetize the nervus alveolaris inferior at the level of the condylus mandibularis but additional branches of CN V_3 are also anesthetized by at injection given at this level (**Table A.14**).

Injection Technique

- Instruct the patient to open as wide as possible.
- Direct the needle from the contralateral premolars and insert the needle high into the mucosa at the level of the dens molaris secundus maxillaris, just distal to the cuspis mesiolingualis (**Fig. A.14A** and **B**).
- Use the incisura intertragica of the ear as an extraoral landmark to help reach the neck of the condylus mandibulae.
- When contact with the neck of the condyle is made, withdraw the needle slightly and aspirate.
- Following a negative aspiration result, slowly inject 1.0 to 1.8 mL of local anesthetic.

Clinical Considerations

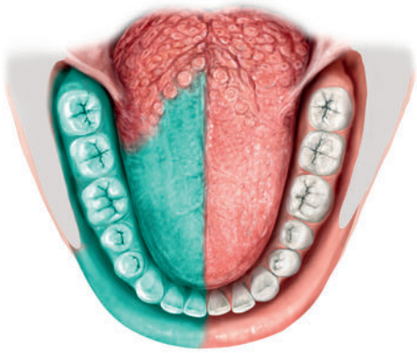
- This injection is useful for multiple procedures on mandibular teeth and buccal soft tissue.
- The rate of failure is lower and there are fewer aspiration issues than with the traditional nervus alveolaris inferior block.

Table A.14 Anesthesia following a Gow–Gates block

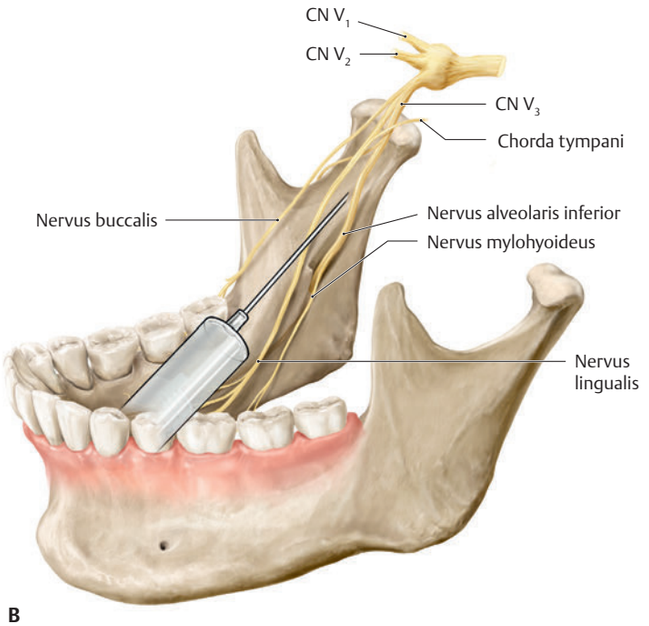
Area anesthetized* (Fig. A.14C)	Nervus (Fig. A.14B)
All mandibular teeth	Nervus alveolaris inferior
All periodontal ligaments, buccal gingiva, mucosa, and supporting alveolar bone from the dens premolaris secundus to the dens molaris tertius	Nervus buccalis
All periodontal ligaments, buccal gingiva, mucosa, and supporting alveolar bone from the dens premolaris secundus to the dens incisivus medialis	Nervus mentalis
All lingual gingiva, supporting bone, and the mucosa of the floor of the mouth	Nervus lingualis (molar region) and its nervus sublingualis branch (premolar to midline)
Anterior two thirds of the tongue	Nervus lingualis
Lower lip	Nervus mentalis
Skin in the temple region and the skin anterior to the ear	Nervus auriculotemporalis
Posterior part of the cheek	Nervus buccalis

* On the same side as the injection.

A



C



B

***Fig. A.14* Gow–Gates block**
A Injection technique.
B Nerves anesthetized, left lateral view.
C Areas anesthetized, superior view.

Akinosi Block

Anatomy

The Akinosi block is an alternative, closed-mouth method of performing a nervus alveolaris inferior block (**Table A.15**). It is useful when the patient has a limited ability to open the mouth, or when the patient has a strong gag reflex that is elicited by conventional nervus alveolaris inferior block.

Table A.15 **Anesthesia following an Akinosi block**

Areas anesthetized* (Fig. A.15D)	Nervus (Fig. A.15B)
All mandibular teeth	Nervus alveolaris inferior
All buccal gingiva, mucosa, and supporting bone from the dens premolaris secundus to the dens incisivus medialis	Nervus mentalis
All lingual gingiva, mucosa, and supporting bone	Nervus lingualis
Anterior two-thirds of the tongue	Nervus lingualis
Lower lip	Nervus mentalis
* On the same side as the injection.	

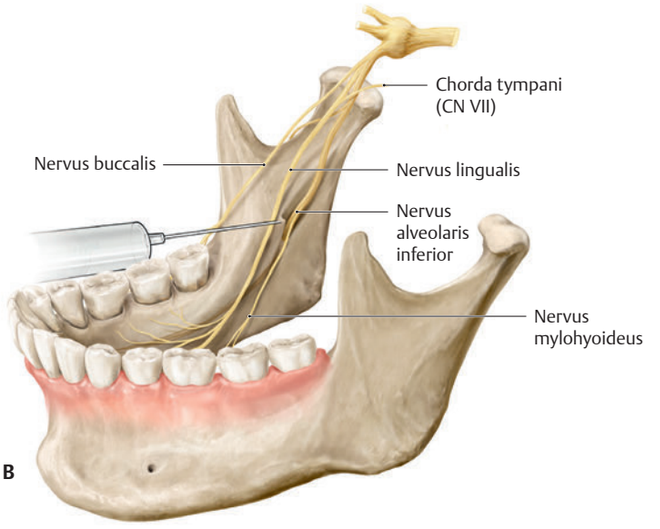
Injection Technique

- Instruct the patient to close his or her mouth.
- Insert the needle into the mucosa between the medial border of the ramus mandibulae and the tuber maxillae at the level of the cervical margin of the dentes molares maxillares.
- Advance the needle parallel to the maxillary occlusal plane ~20 to 25 mm. At this depth, the tip of the needle should be in the middle of the spatium pterygomandibulare near the nervi alveolaris inferior and lingualis (**Fig. A.15A** and **B**).
- Following a negative aspiration result, slowly inject the full cartridge of local anesthetic (1.8 mL).

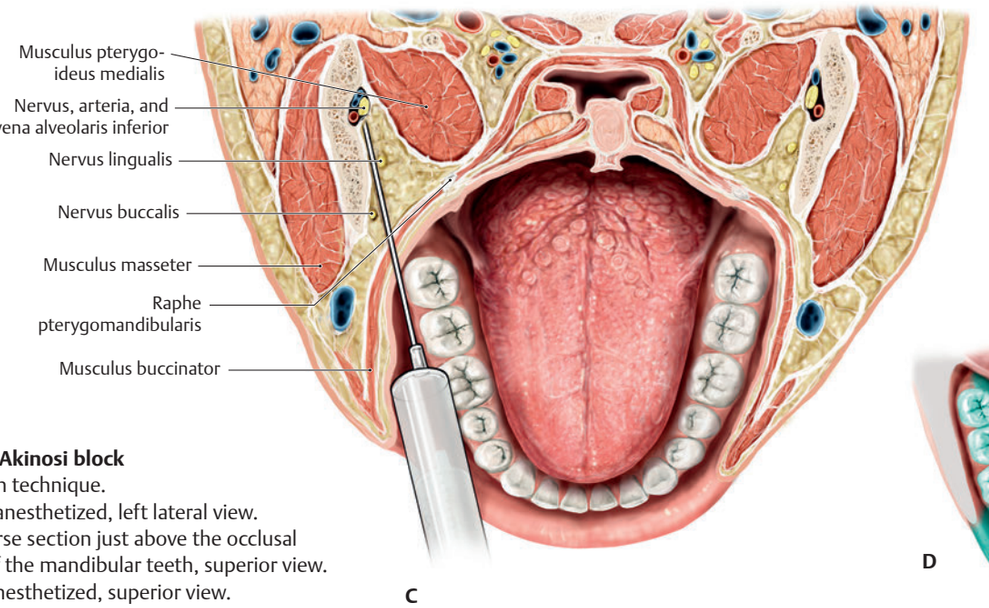
Clinical Considerations

- This injection is sufficient for cavity preparations, pulpal procedures, and surgical procedures involving the lingual aspect of the mandibular teeth.
- Extractions of the dentes molares mandibulares require supplemental anesthesia of the nervus buccalis.

A



B



C

D

Fig. A.15 **Akinosi block**
A Injection technique.
B Nerves anesthetized, left lateral view.
C Transverse section just above the occlusal plane of the mandibular teeth, superior view.
D Areas anesthetized, superior view.

Nervus buccalis Block

Anatomy

The nervus buccalis is a branch of the nervus mandibularis (**Table A.16**). It passes along the medial side of the ramus mandibulae anterior to the nervus alveolaris inferior. It then crosses the anterior border of the ramus mandibulae. Its branches innervate the buccal gingiva between the dentes premolaris secundus and molares mandibulares, as well as the trigonum retromolare.

Table A.16 **Anesthesia following a nervus buccalis block**

Areas anesthetized* (Fig. A.16A)	Nervus (Fig. A.16B)
Buccal gingiva, mucosa, and supporting bone from the dens premolaris secundus mandibularis to the last dens molaris and trigonum retromolare	Nervus buccalis (from CN V_3)

Injection Technique

- Insert the needle into the buccal mucosa posterior to the last dens molaris. It will only penetrate ~2 mm (**Fig. A.16A** and **B**).
- Following a negative aspiration result, inject ~0.5 mL of local anesthetic.

Clinical Considerations

- This injection is used to supplement a nervus alveolaris inferior block for extractions or surgical procedures involving the dentes premolares secundi mandibulares to molares.

Supplementary Nervus Sublingualis Infiltration

Anatomy

The nervus lingualis passes downward together with the nervus alveolaris inferior and communicates with the chorda tympani of the nervus facialis just before reaching the foramen mandibulae. This connection gives off secretory fibers to the glandulae submandibularis and sublingualis via the ganglion submandibulare and taste fibers to the anterior two-thirds of the tongue. The trunk of the nervus lingualis gives off branches that innervate the lingual gingiva in the molar region. The lingual gingiva and mucosa of the floor of the mouth are innervated by the nervus sublingualis, a branch of the nervus lingualis (**Table A.17**).

Table A.17 **Supplementary infiltration of nervus sublingualis**

Areas anesthetized*	Nervus
Lingual gingiva and supporting bone, and the mucosa of the floor of the mouth in the vicinity of the infiltration	Nervus sublingualis

* On the same side as the injection.

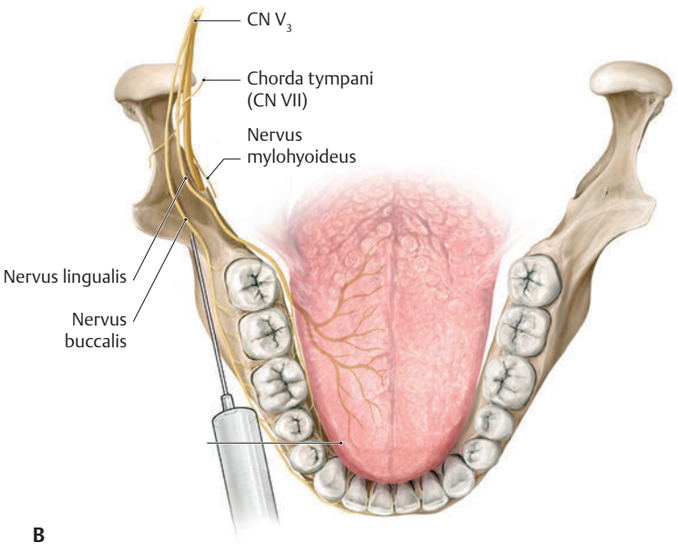
Injection Technique

- Introduce the needle just below the attached gingiva on the lingual side of the tooth requiring lingual anesthesia.
- Following a negative aspiration result, slowly inject a small amount of local anesthetic.

Clinical Considerations

- This injection is used to supplement a mucobuccal fold infiltration or nervus mentalis block for extractions of the dentes incisivi, caninus, and premolares mandibulares. It is not necessary for extraction of the dentes molares mandibulares because the nervus lingualis trunk is anesthetized as part of the nervus alveolaris inferior block given in these cases.
- Hematoma formation may occur if the injection lacerates the vessels in the floor of the mouth.

A



B

C

Fig. A.16 **Nervus buccalis block**
A Injection technique.
B Nerves anesthetized, superior view.
C Areas anesthetized, superior view.

Factual Questions

Chapter 1 Embryology of the Head & Neck

1. The skeletal elements that develop within the arcus pharyngeus primus include the
   A. Os hyoideum
   B. Os nasale
   C. Os palatinum
   D. Stapes
   E. Os occipitale
2. The foramen incisivum is an anatomical landmark between the
   A. Palata durum and molle
   B. Palata primarium and secundarium
   C. Processus palatini laterales
   D. Os palatinum and maxilla
   E. Prominentiae nasales mediales
3. The nervi craniales that carry sensory information from the part of the tongue derived from the eminencia hypobranchialis are the
   A. Nervi glossopharyngeus and vagus
   B. Nervi trigeminus and facialis
   C. Nervi vagus and hypoglossus
   D. Nervi facialis and glossopharyngeus
   E. Nervi trigeminus and glossopharyngeus
4. Secondary cleft palatum, without primary cleft palatum or cleft lip, results from the failure of fusion of the
   A. Prominentia maxillaris and prominentia nasalis medialis
   B. septum nasi and prominentia maxillaris
   C. Prominentia maxillaris and processus palatinus lateralis
   D. Left and right processus palatinus lateralis
   E. Intermaxillary segment
5. The intermaxillary segment of the developing face provides the alveolar sockets for the
   A. Dentes molares mandibulares
   B. Dentes canini maxillares
   C. Dentes decidui
   D. Dentes premolares mandibulares
   E. Dentes incisivi maxillares
6. A child presents with a midline swelling at the base of of the tongue. Magnetic resonance imaging (MRI) shows a midsagittal growth referred to as a lingual cyst by the radiologist. The embryological origin of this lingual cyst is a
   A. Persistent sulcus pharyngeus primus
   B. Nonmigrating glandula thyroidea
   C. Laryngeotracheal diverticulum
   D. Saccus pharyngeus secundus
   E. Metastasis of the tonsilla lingualis

Chapter 2 Ossa Cranii

7. The palatum durum has passages for branches of the nervus maxillaris division of the nervus trigeminus that include the foramen incisivum for the nervus nasopalatinus and the
   A. Foramen palatinum majus for the nervus palatinus major
   B. Foramen infraorbitale for the nervus infraorbitalis
   C. Foramen mentale for the nervus mentalis
   D. Foramen rotundum for the nervus maxillaris
   E. Foramen sphenopalatinum for the nervus nasopalatinus
8. The foramen mandibulae of the ramus is protected by the bony _____ in a superoanterior position.
   A. Spina mentalis
   B. Hamulus pterygoideus
   C. Processus coronoideus
   D. Lingula mandibulae
   E. Processus condylaris
9. The anteromedial floor of the canalis caroticus in the pars petrosa of the os temporale is “open” to the pars nasalis pharyngis through the
   A. Foramen ovale
   B. Foramen lacerum
   C. Foramen jugulare
   D. Foramen spinosum
   E. Foramen mastoideum
10. The fossa cranii anterior is separated from the fossa cranii media by the
    A. Lamina lateralis processus pterygoidei of the os sphenoidale
    B. Lamina perpendicularis of the os ethmoidale
    C. Ala minor of the os sphenoidale
    D. Pars petrosa of the os temporale
    E. Crista frontalis of the os frontalis
11. What structure on the internal surface of the lateral wall of the cranial vault crosses over the area indicated by pterion?
    A. Sulcus arteriae meningeae mediae
    B. Fossa hypophysialis
    C. Sulcus sinus sigmoidei
    D. Meatus acusticus internus
    E. Crista galli of the os ethmoidale
12. The foramen rotundum exits the fossa cranii media through which bone?
    A. Pars petrosa ossis temporalis
    B. Os ethmoidale
    C. Os occipitale
    D. Mandibula
    E. Os sphenoidale
13. The majority of the palatum durum of the cavitas oris is formed from the union of the lamina horizontalis of the os palatinum with the
    A. Lamina media processus pterygoidei of the os sphenoidale
    B. Lamina perpendicularis of the os ethmoidale
    C. Processus palatinus of the maxilla
    D. Pars squamosa of the os temporale
    E. Alae of the vomer

Chapter 3 Vasculature & Lymphatics of the Head & Neck

14. The branch of the mandibular part of the arteria maxillaris that passes through the foramen spinosum is the
    A. arteria meningea media
    B. Arteria temporalis profunda
    C. Arteria sphenopalatina
    D. Arteria carotis interna
    E. Arteria ophthalmica
15. The arteria alveoloaris superior, supplying blood to the dentes molares mandibulares, is a branch of which artery?
    A. Arteria facialis
    B. Arteria maxillaris
    C. Arteria lingualis
    D. Arteria sphenopalatina
    E. Arteria carotis interna

16. The arteria vertebralis is a branch of the

    A. Arteria carotis externa
    B. Arteria carotis communis
    C. Arteria subclavia
    D. Arcus aortae
    E. Truncus brachiocephalicus

17. The danger zone (triangle) of the face deals with venous drainage from superficial veins into deep veins and intracranial venous sinuses. The direct communication between the vena angularis (vena facialis) and the sinus cavernosus is via the

    A. Plexus pterygoideus
    B. Vena retromandibularis
    C. Vena lingualis
    D. Venae ophthalmicae
    E. Truncus brachiocephalicus

18. While weightlifting, a 22-year-old man attempting a personal record on the parallel back squat drops the barbell across his upper back. The compression from the barbell ruptures his left arteria dorsalis scapulae, and immediately he starts to feel blood pooling deep to his trapezius and rhomboid muscles. Compression to the _____ will stop the bleeding.

    A. Truncus brachiocephalicus
    B. Arteria carotis communis
    C. Arteria thoracoacromialis
    D. Truncus costocervicalis
    E. Truncus thyrocervicalis

19. The arteria cerebri media is a direct branch of which artery?

    A. Arteria carotis communis
    B. Arteria carotis externa
    C. Arteria carotis interna
    D. Arteria basilaris
    E. Arteria meningea media

20. Normal venous drainage of the sinus cavernosus is directly through the

    A. Sinus rectus
    B. Sinus petrosi
    C. Vena jugularis externa
    D. Plexus basilaris
    E. Sinus maxillaris

21. The nodi lymphoidei parotidei superficiales drain directly into the nodi lymphoidei _____ as the lymph drains back toward the cardiovascular system through either the ductus lymphaticus dexter or ductus thoracicus.

    A. Occipitales
    B. Faciales
    C. Nuchal
    D. Laryngeotracheal
    E. Cervicales profundi

Chapter 4 Neuroanatomy & Innervation of the Head & Neck

22. The passageway in the skull through which the nervus abducens passes is the

    A. Fissura orbitalis superior
    B. Foramen rotundum
    C. Foramen ovale
    D. Foramen infraorbitale
    E. Foramen spinosum

23. Which nerve innervates the auris media muscle that modulates the motion of the stapes?

    A. Nervus opticus
    B. Nervus oculomotorius
    C. Nervus vestibulocochlearis
    D. Nervus trigeminus
    E. Nervus facialis

24. The extraocular muscle innervated by the nervus trochlearis is the

    A. Musculus rectus lateralis
    B. Musculus obliquus superior
    C. Musculus orbicularis oculi
    D. Musculus rectus capitis lateralis
    E. Musculus dilator pupillae

25. The nervus vagus exits the fossa cranii posterior at the

    A. Foramen jugulare
    B. Meatus acusticus internus
    C. Canalis condylaris
    D. Foramen magnum
    E. Foramen lacerum

26. The innervation for the musculus hyoglossus is the

    A. Ansa cervicalis
    B. Nervus facialis
    C. Nervus hypoglossus
    D. Nervus mylohyoideus
    E. Nervus laryngeus recurrens

27. The parasympathetic innervation to the glandula parotidea travels through the

    A. Chorda tympani
    B. Nervus petrosus major
    C. Nervus petrosus profundus
    D. Nervus tympanicus
    E. Nervus lingualis

28. The C8 nervus spinalis exits the canalis vertebralis

    A. Above the C7 vertebra
    B. Below the C7 vertebra
    C. Below the C8 vertebra
    D. Through the C8 foramen transversarium
    E. Never because there is no C8 nervus spinalis

29. During a routine physical, a patient comments to his primary care physician that he has tingling and a sensation of cold that is focused on the top of his right shoulder. The likely cause of this condition is

    A. Osteophyte in the C1–C2 foramen intervertebrale
    B. Compression of the nervus axillaris
    C. C3–C4 slipped disk
    D. Referred pain from the splen
    E. Avulsion of the C6 nervus spinalis

30. The central nervous structure that develops from the embryological myelencephalon is the

    A. Pedunculus cerebri
    B. Thalamus
    C. Pons
    D. Medulla oblongata
    E. Tectum

31. The voluntary motor cortex in the hemispherium cerebri is separated from the conscious body sensation cortex by the

    A. Sulcus calcarinus
    B. Sulcus parietooccipitalis
    C. Sulcus lateralis
    D. Fissura longitudinalis cerebri
    E. Sulcus centralis

32. The flow of liquor cerebrospinalis (CSF) in an individual with noncommunicating hydrocephalus can be blocked by the plexus choroideus in the
    A. Aqueductus cerebri
    B. Pontomedullary cistern
    C. Cisterna cerebellomedullaris
    D. Confluens sinuum
    E. Granulationes arachnoideae

Chapter 5 Face & Scalp

33. Which facial muscle can act as an oral sphincter?
    A. Musculus risorius
    B. Musculus depressor labii inferioris
    C. Musculus orbicularis oris
    D. Musculus levator anguli oris
    E. Musculus orbicularis oculi

34. Each of the following muscles is innervated by a branch of the nervus facialis passing through the glandula parotidea except the
    A. Musculus platysma
    B. Musculus zygomaticus major
    C. Musculus posterior auricular
    D. Musculus risorius
    E. Musculus buccinator

35. A facial muscle attached to the processus alveolares of the mandibula and maxilla is the
    A. Musculus depressor anguli oris
    B. Musculus buccinator
    C. Musculus levator labii superioris
    D. Musculus zygomaticus minor
    E. Musculus mentalis

36. Infections of the scalp are most likely to spread in which layer?
    A. Skin
    B. Connective tissue
    C. Aponeurosis epicranialis
    D. Loose areolar connective tissue
    E. Pericranium

37. Which of the following arteries of the face is derived from the arteria carotis interna?
    A. Arteria supraorbitalis
    B. Arteria facialis
    C. Ramus lateralis nasi arteriae facialis
    D. Arteria temporalis superficialis
    E. Arteria transversa faciei

38. The nerve that supplies the skin of the posterior scalp (occiput) is the
    A. Nervus maxillaris
    B. Nervus transversus cervicalis
    C. Nervus auricularis magnus
    D. Nervus occipitalis major
    E. Nervus facialis

39. The vena facialis drains into the
    A. Vena angularis
    B. Vena jugularis anterior
    C. Vena jugularis externa
    D. Vena facialis communis
    E. Vena profunda faciei

40. Which nerve carries sensory information from the upper lip?
    A. Ramus alveolaris superior anterior
    B. Ramus buccalis nervi facialis
    C. Nervus mentalis
    D. Nervus supraorbitalis
    E. Nervus infraorbitalis

Chapter 6 Fossae Temporalis, Infratemporalis, & Pterygopalatina

41. The insertion (posterior attachment) of the musculus pterygoideus lateralis is the
    A. Tuberositas pterygoidea on the medial angle of the mandibula
    B. Facies medialis of the processus coronoideus of the mandibula
    C. Facies medialis of the processus zygomaticus of the os temporale
    D. Fovea pterygoidea and the processus condylaris of the mandibula
    E. Linea temporalis inferior of the ossa frontale, temporale, and parietale

42. Much of the weight of the mandibula is supported by the
    A. Musculus mylohyoideus
    B. Ligamentum sphenomandibulare
    C. Musculus digastricus
    D. Ligamentum pterygospinosum
    E. Musculus buccinator

43. Which muscle of mastication is the primary retractor (retruder) of the mandibula?
    A. Musculus masseter
    B. Musculus pterygoideus medialis
    C. Musculus temporalis
    D. Musculus pterygoideus lateralis
    E. Musculus mylohyoideus

44. The action of the musculus pterygoideus lateralis is to
    A. Protrude the mandibula
    B. Tense the palatum molle
    C. Depress the os sphenoidale
    D. Elevate the os hyoideum
    E. Retract the mandibula

45. Which structure attaches to the lingula of the mandibula?
    A. Musculus masseter
    B. Ligamentum sphenomandibulare
    C. Musculus temporalis
    D. Ligamentum stylomandibulare
    E. Tuba auditiva

46. The nerve(s) that emerge from between the two heads of the musculus pterygoideus lateralis is/are the
    A. Nervus alveolaris inferior
    B. Nervus lingualis
    C. Nervi temporales profundi
    D. Nervus buccalis
    E. Both A and B

47. Which of the following is not a branch of the arteria maxillaris?
    A. Arteria meningea media
    B. Arteria tympanica inferior
    C. Arteria auricularis profunda
    D. Arteria palatina descendens
    E. Arteria canalis pterygoidei

48. Sensation to the TMJ is provided by which of the following branches of the nervus mandibularis?
    A. Nervus alveolaris inferior
    B. Nervus auriculotemporalis
    C. Nervus lingualis
    D. Nervus pterygoideus lateralis
    E. Nervus buccalis

49. Through which opening does the fossa pterygopalatina communicate with the fossa infratemporalis?
    A. Canalis palatinus major
    B. Canalis pterygoideus
    C. Foramen sphenopalatinum
    D. Foramen rotundum
    E. Fissura pterygomaxillaris

50. The ganglion pterygopalatinum receives preganglionic parasympathetic fibers traveling on which nerve?
    A. Nervus maxillaris
    B. Chorda tympani
    C. Nervus petrosus major
    D. Nervus petrosus minor
    E. Nervus petrosus profundus

51. Which bone forms the superior boundary of the fossa pterygopalatina?
    A. Os sphenoidale
    B. Maxilla
    C. Os palatinum
    D. Os temporale
    E. Vomer

Chapter 7 Nose & Cavitas Nasi

52. The cavitas nasi is enclosed by the os ethmoidale, vomer, maxilla, os sphenoidale, os nasale, os lacrimale, conchae nasi inferiores, and which other bone?
    A. Os palatinum
    B. Os zygomaticum
    C. Mandibula
    D. Os parietale
    E. Os occipitale

53. The sinus frontalis communicates with the _____ of the respiratory system.
    A. Meatus inferior
    B. Meatus medius
    C. Meatus superior
    D. Pars nasalis pharyngis
    E. Recessus sphenoethmoideus

54. Kiesselbach's area, the anastomosis of nasal septal arteries, links together branches of the arteriae labialis superior, ethmoidalis anterior, palatina major, and _____.
    A. Alveolaris posterior superior
    B. Meningea media
    C. Sphenopalatina
    D. Pharyngea ascendens
    E. Arteria tympanica anterior

55. Innervation to the mucosa covering the vomer bone is through which nerve?
    A. Nervus olfactorius
    B. Nervus ethmoidalis anterior
    C. Nervus palatinus major
    D. Nervus nasopalatinus
    E. Nervus alveolaris superior posterior

56. A patient comes to the dentist's office complaining of pain from his left dens molaris secundus maxillaris. The dentist examines the tooth and decides that it needs to be extracted. He knows that care needs to be taken to avoid introducing infection into the sinus paranasalis just superior to the tooth. Which paranasal sinus can potentially be affected by this extraction?
    A. Sinus frontalis
    B. Cellulae ethmoidales
    C. Cellulae mastoideae
    D. Sinus sphenoidalis
    E. Sinus maxillaris

57. A pituitary tumor (macroadenoma) causing headache and loss of peripheral vision for an individual needs to be surgically treated. The surgeon decides to access the tumor, for removal, through which air sinus separating the glandula pituitaria from the cavitas nasi?
    A. Sinus frontalis
    B. Sinus ethmoidalis
    C. Sinus mastoideus
    D. Sinus sphenoidalis
    E. Sinus maxillaris

Chapter 8 Cavitas Oris & Pharynx

58. Which suprahyoid muscle is innervated by the nervus facialis?
    A. Musculus mylohyoideus
    B. Musculus hyoglossus
    C. Venter posterior musculi digastrici
    D. Musculus geniohyoideus
    E. Musculus stylopharyngeus

59. Taste information from the posterior one-third of the tongue travels along the nervus glossopharyngeus via the ganglion inferius to the nucleus tractus solitarii (gustatory part) in the open medullary part of the truncus encephali. From here it travels through the tractus trigeminothalamicus posterior to reach the _____ of the thalamus. The final leg of the tract brings taste information to the insula and gyrus postcentralis of the hemispherium cerebri.
    A. Nucleus ventralis anterior
    B. Nucleus dorsalis lateralis
    C. Pulvinar
    D. Nucleus geniculatus medialis
    E. Nucleus ventralis posteromedialis

60. Which muscle of the palatum molle is connected to the pars cartilaginea tubae auditivae?
    A. Musculus tensor veli palatini
    B. Musculus palatoglossus
    C. Musculus palatopharyngeus
    D. Musculus tensor tympani
    E. Musculus constrictor pharyngis superior

61. The part of Waldeyer's ring (anulus lymphoideus pharyngis) most closely associated with the epiglottis is the
    A. Tonsilla tubaria
    B. Tonsilla lingualis
    C. Tonsilla pharyngealis
    D. Tonsilla palatina
    E. Tonsilla adenoidea

62. The tooth layer immediately deep to the enamelum is the
    A. Periodontal ligament
    B. Cementum
    C. Pulpa
    D. Dentinum
    E. Alveolar bone

63. Which of the following dentes permanentes (secondary dentition) erupt at ~6 to 8 years of age?
    A. Dens caninus
    B. 1st dens premolaris
    C. 2nd dens premolaris
    D. 1st dens molaris
    E. 2nd dens molaris

64. The glandulae salivariae sublinguales receive postganglionic parasympathetic innervation from which ganglion?
    A. Ganglion cervicale superius
    B. Ganglion pterygopalatinum
    C. Ganglion ciliare
    D. Ganglion oticum
    E. Ganglion submandibulare

65. The glandula parotidea produces which type of secretions?
    A. Mucous
    B. Serous
    C. Mixed mucous and serous

66. Infections from which teeth can spread to the spatia peripharyngea?
    A. Dentes molares maxillares
    B. Dentes canini maxillares
    C. Dentes premolares mandibulares
    D. Dentes canini mandibulares
    E. Dentes incisivi mandibulares

67. Which potential space is located inferior to the linea mylohyoidea inferior and lateral to the musculus mylohyoideus?
    A. Sublingual
    B. Submandibular
    C. Masticator
    D. Tonsillar
    E. Parotid

Chapter 9 Orbita & Eye

68. The artery running through the canalis opticus to supply blood to the orbita is a branch of the
    A. Arteria meningea media
    B. Arteria temporalis profunda
    C. Arteria sphenopalatina
    D. Arteria carotis interna
    E. Arteria ophthalmica

69. The extraocular muscle innervated by the nervus trochlearis is the
    A. Venter anterior musculi digastrici
    B. Musculus rectus lateralis
    C. Musculus obliquus inferior
    D. Musculus rectus capitis lateralis
    E. Musculus obliquus superior

70. Through which passageway in the skull does the ramus superior of the nervus oculomotorius pass?
    A. Fissura orbitalis superior
    B. Foramen rotundum
    C. Foramen ovale
    D. Foramen infraorbitale
    E. Foramen spinosum

71. The quickest impulse conduction through the retina links the rod or cone photoreceptors to the retinal ganglion cells through the
    A. Horizontal cell
    B. Bipolar cell
    C. Amacrine cell
    D. Purkinje cell
    E. Müller cell

72. An individual complaining of tunnel vision (bitemporal hemianopia) asks her dentist to explain where the problem might be occurring. She also mentions that she is regularly experiencing headache, a change in her menstrual cycle, and significant weight gain. The dentist explains that there is a chance of a pituitary tumor (macroadenoma) creating pressure on the
    A. Nervus opticus
    B. Tractus opticus
    C. Chiasma opticum
    D. Pars retrolentiformis capsulae internae
    E. Splenium corporis callosi

Chapter 10 Ear

73. The blood supply to the auris externa includes the arteria auricularis posterior and the
    A. Arteria transversa faciei
    B. Arteria temporalis superficialis
    C. Arteria sphenopalatina
    D. Arteria carotis interna
    E. Arteria occipitalis

74. Taste fibers traveling through the cavitas tympanica are carried by a nerve that is a branch of the
    A. Nervus trigeminus
    B. Nervus facialis
    C. Nervus vestibulocochlearis
    D. Nervus glossopharyngeus
    E. Nervus vagus

75. The ossicula auris mediae that fits into the fenestra vestibuli of the auris interna is the
    A. Malleus
    B. Os pisiforme
    C. Stapes
    D. Os naviculare
    E. Incus

76. The nervus vestibulocochlearis exits the fossa cranii posterior to reach the auris interna of the os temporale through the
    A. Hiatus canalis nervi petrosi majoris
    B. Meatus acusticus externus
    C. Canaliculus mastoideus
    D. Meatus acusticus internus
    E. Foramen stylomastoideum

77. The right canalis semicircularis anterior of the vestibulocochlear apparatus of the pars petrosa of the os temporale is at a parallel plane to the
    A. Right canalis semicircularis posterior
    B. Right canalis semicircularis lateralis
    C. Left canalis semicircularis anterior
    D. Left canalis semicircularis lateralis
    E. Left canalis semicircularis posterior

78. To detect sound, vibration of the hair cells is necessary. Movement at the fenestra vestibularis of the auris media results in pressure waves that travel through the perilympha. Although the hair cells are not surrounded by perilympha, they are attached to a flexible structure separating perilymph a` from endolympha called the
    A. Lamina basilaris
    B. Ligamentum spirale
    C. Membrana vestibularis
    D. Membrana tectoria
    E. Helicotrema

79. The part of the auditory system that is critical for the localization of sound is the
    A. Nucleus vestibularis
    B. Musculus tensor tympani
    C. Ganglion spirale
    D. Corpus geniculatum laterale
    E. Lemniscus medialis

Chapter 11 Bones, Ligaments, & Muscles of the Neck

80. Which muscle draws the os hyoideum forward and is innervated by the ramus anterior of the C1 nervus spinalis?
    A. Musculus mylohyoideus
    B. Musculus geniohyoideus
    C. Musculus stylohyoideus
    D. Musculus omohyoideus
    E. Musculus sternohyoideus

81. The muscle of the neck that rotates the head to the contralateral side is the
    A. Musculus rectus capitis posterior major
    B. Musculus longissimus capitis
    C. Musculus rectus capitis lateralis
    D. Musculus splenius capitis
    E. Musculus sternocleidomastoideus

82. The origin (proximal attachment) of which back muscle includes the processus spinosus of the T6 vertebra?
    A. Splenius cervicis
    B. Musculus levator costarum longus
    C. Musculus serratus posterior superior
    D. Musculus iliocostalis thoracis
    E. Musculus longus colli

83. What is the innervation to the musculus geniohyoideus?
    A. Nervus mylohyoideus
    B. Nervus facialis
    C. Ramus anterior of the C1 nervus spinalis
    D. Nervus alveolaris inferior
    E. Nervus hypoglossus

Chapter 12 Neurovascular Topography of the Neck

84. Which pharyngeal space lies posterior to the tongue and lateral to the plica glossoepiglottica mediana?
    A. Vallecula epiglottica
    B. Recessus piriformis
    C. Rima glottidis
    D. Foramen caecum
    E. Fossa tonsillaris

85. The musculus scalenus medius originates on the C1 and C2 processus transversi and the C3–C7 tubercula posteriora, and it inserts into the
    A. Angulus superior scapulae
    B. Costa I
    C. Costa II
    D. Pars basilaris ossis occipitalis
    E. Manubrium sterni

86. Name the neck triangle that provides the best access to the nervus accessorius.
    A. Trigonum submandibulare
    B. Trigonum musculare
    C. Trigonum carotideum
    D. Occipital
    E. Trigonum omoclaviculare

87. Which nervus cranialis travels from the base of the skull to the mediastinum in the vagina carotica?
    A. Nervus facialis
    B. Nervus glossopharyngeus
    C. Nervus vagus
    D. Nervus accessorius
    E. Nervus hypoglossus

88. Bacterial infection of the cavitas oris may invade the spatium parapharyngeum and can easily spread inferiorly to the
    A. Sinus cavernosus
    B. Pulmo
    C. Gaster
    D. Mediastinum
    E. Spatium subarachnoideum

89. The radix superior of the ansa cervicalis contains fibers from the
    A. Nervus vagus
    B. Nervus hypoglossus
    C. C3 ramus anterior
    D. C2 ramus posterior
    E. C1 ramus anterior

90. The vena jugularis externa collects blood directly from the posterior division of the vena retromandibularis, vena auricularis posterior, and
    A. Vena transversa cervicis
    B. Vena thyroidea inferior
    C. Plexus pterygoideus
    D. Vena facialis
    E. Vena lingualis

Chapter 13 Larynx & Glandula Thyroidea

91. The cartilago epiglottica is attached to the cartilago_____ of the respiratory system.
    A. Thyroidea
    B. Cricoidea
    C. Arytenoidea
    D. Corniculata
    E. Trachealis

92. The only laryngeal muscle that abducts the plicae vocales and opens the rima glottidis is the
    A. Musculus cricoarytenoideus posterior
    B. Musculus cricothyroideus
    C. Musculus cricoarytenoideus lateralis
    D. Musculus arytenoideus transversus
    E. Musculus thyroarytenoideus

93. The part of the glandula thyroidea that stretches anterior to the prominentia laryngea toward the foramen caecum of the tongue is the
    A. Lobus lateralis
    B. Isthmus glandulae thyroideae
    C. Lobus pyramidalis
    D. Glandula parathyroidea superior
    E. Glandula parathyroidea inferior

Chapter 15 Rest of Body Anatomy

94. Impingement of the nervus suprascapularis as it runs inferior to the ligamentum transversum scapulae superius can result in paralysis of the
    A. Musculus infraspinatus
    B. Musculus subclavius
    C. Musculus teres major
    D. Musculus rhomboideus minor
    E. Musculus deltoideus

95. The vena brachialis drains into the _____ to return blood to the heart.
    A. Vena cephalica
    B. Vena axillaris
    C. Vena brachiocephalica
    D. Vena jugularis interna
    E. Vena subclavia

96. The insertion/distal attachment of the musculus biceps brachii is the
    A. Lateral sulcus intertubercularis humeri
    B. Processus coracoideus scapulae
    C. Tuberositas ulnae
    D. Fossa olecrani humeri
    E. Tuberositas radii

97. The left 8th vena intercostalis posterior drains directly into the
    A. Vena cava inferior
    B. Vena cava superior
    C. Vena hemiazygos
    D. Vena azygos
    E. Ductus thoracicus

98. The ramus marginalis sinister of the heart branches off the

    A. Ramus interventricularis anterior
    B. Ramus interventricularis posterior
    C. Arteria coronaria dextra
    D. Ramus circumflexus
    E. Venae cordis minimae

99. An elderly man presents in the emergency department with sudden onset of breathlessness and chest pain along the superior posterolateral left chest wall. Imaging reveals a wedge-shaped opaque structure abutting the pleura, signifying a pulmonary infarction distal to a pulmonary embolism. The pulmonary lobe most likely affected is the

    A. Segmentum apicoposterius of the lobus superior pulmonis sinistri
    B. Segmentum apicale of the lobus superior pulmonis dextri
    C. Segmentum laterale of the lobus medius pulmonis dextri
    D. Segmentum lingulare of the lobus superior pulmonis sinistri
    E. Segmentum superius of the lobus inferior pulmonis sinistri

Appendix A Anatomy of Local Anesthesia for Dentistry

100. During the administration of a nervus alveolaris inferior, the nee dle passes through which structure?

    A. Musculus pterygoideus medialis
    B. Musculus pterygoideus lateralis
    C. Musculus buccinator
    D. Raphe pterygomandibularis
    E. Fascia parotidea

Answer Explanations

Chapter 1 Embryology of the Head & Neck

1. **C** The os palatinum develops from the midline fusion of the prominentia maxillaris of the arcus pharyngeus primus.

   A The cornu minus of the os hyoideum develops from the arcus pharyngeus secundus; the corpus and cornu majus of the os hyoideum develop from the arcus pharyngeus tertius.
   B The ossa nasalia develop from the prominentia frontalis, a structure that is developmentally distinct from the arcus pharyngei.
   D The stapes, the most medial of the ossicula auris mediae, develops from the posterior aspect of the arcus pharyngeus secundus.
   E The os occipitale develops from parachordal cartilage at the rostral end of the notochorda and from occipital somites.

2. **B** The foramen incisivum is a landmark between the palata primarium and secundarium.

   A The landmark between the palata durum and molle is the posterior edge of the lamina horizontalis of the os palatinum.
   C The landmark between the left and right lateral processus palatini is the sutura intermaxillaris of the palatum durum.
   D The landmark between the os palatinum and maxilla is the sutura palatina transversa (sutura palatomaxillaris).
   E The landmark between the left and right prominentiae nasales mediales is the septum nasi, the intermaxillary segment of the labium superius, and the philtrum.

3. **A** The eminentia hypopharyngea, which arises in the floor of the pharynx between the 3rd and 4th arcus pharyngei, gives rise to the posterior one-third of the tongue. It receives general (pain, touch) and special (taste) sensory innervation from both the nervi craniales glossopharyngeus and vagus (CN IX and X, respectively. The nervus vagus carries general and taste sensation from the root of the tongue and epiglottis, while the nervus glossopharyngeus receives general and taste sensation from the majority of the posterior one-third of the tongue).

   B The nervus trigeminus receives general sensory innervation, and the nervus facialis receives special sensory innervation from the anterior two-thirds of the tongue, which develops in the floor of the pharynx between the 1st and 2nd arcus pharyngei.
   C Although the nervus vagus does carry sensory innervation from the region of the eminentia hypopharyngea, the nervus hypoglossus carries no sensory innervation. Instead, the nervus hypoglossus carries general somatic motor innervation to the tongue.
   D, E Although the nervi facialis, trigeminus, and glossopharyngeus all carry sensory information from the tongue, only the nervus glossopharyngeus carries information from the eminentia hypopharyngea. The nervus facialis carries special sensory information (taste) from the anterior two-thirds of the tongue; the nervus trigeminus carries general sensory information from the anterior two-thirds of the tongue.

4. **D** Failure of fusion of the left and right processus palatinus lateralis results in secondary cleft palatum.

   A Failure of fusion of the prominentia maxillaris with the prominentia nasalis medialis will result in a cleft lip, with no effect on the secondary palatum, although it may affect the primary palatum.
   B Failure of fusion of the septum nasi with the maxillaris prominentius will result in a persistent passage between the left and right cavitates nasi but will have no effect on the palatum durum of the cavitas oris.
   C The processus palatini laterales are extensions of the prominentia maxillaris and begin as a single rostral part of the arcus pharyngeus primus and therefore never undergo fusion. They remain as a single bony structure throughout life.
   E Failure of fusion of the intermaxillary segment results from failure of fusion of the left and right prominentiae nasales mediales. This would result in a midline cleft lip and a primary cleft palatum.

5. **E** The dentes incisivi maxillares, both decidui and permanentes (therefore not answer choice C), are supported by the intermaxillary segment of the upper jaw.

   A, D The dentes molares and premolares mandibulares are supported by the caudal part of the arcus pharyngeus primus specifically, the prominentia mandibularis.
   B The dentes canini maxillares are supported by the prominentia maxillaris, specifically, the lateral part of the processus palatinus lateralis.

6. **B** A nonmigrating glandula thyroidea would result in a lingual cyst presenting as a midline swelling at the base of the tongue in the region of foramen caecum. During normal development the glandula thyroidea passes from the pars oralis pharyngis into the neck by invaginating the tongue through a path indicated by foramen caecum.

   A A persistent sulcus pharyngeus primus would result in a deformed auricula auris, a surface defect (depression) in the cheek, and an enlarged mouth (macrostomia).
   C The laryngeotracheal diverticulum is a normal embryological structure that gives rise to the connection between the respiratory and digestive systems. This persists in the adult as the aditus laryngis and the rima glottidis.
   D The saccus pharyngeus secundus becomes the sinus of the tonsilla palatina. It is laterally located in the pars oralis pharyngis, and it normally persists in the adult.
   E Metastasis of the tonsilla lingualis may present as a midline swelling of the root of the tongue, but it likely would first involve the surface of the tongue, and it would migrate laterally as well as deeper into the structure of the tongue. It is unlikely to remain solely at the midline. Such a metastasis would not be referred to as a lingual cyst.

Chapter 2 Ossa Cranii

7. **A** The foramen palatinum majus of the os palatinum at the posterior margin of the palatum durum allows for passage for the nervus palatinus major (and arteria palatina major), a branch of the nervus maxillaris (and artery).

   B The foramen infraorbitale allows for passage of the nervus infraorbitalis (and arteria infraorbitalis), a branch of the nervus maxillaris division of the nervus trigeminus, although these vessels do not supply the palatum durum.
   C The foramen mentale of the mandibula allows passage for the terminal branches of the nervus alveolaris inferior (and arteria alveolaris inferior). The nervus alveolaris inferior is a branch of the nervus mandibularis division of the nervus trigeminus, which innervates the inferior teeth. The arteria alveolaris inferior is a branch of the arteria maxillaris.
   D The foramen rotundum of the os sphenoidale is the passage for the unbranched (except ramus meningeus) nervus maxillaris division of the nervus trigeminus to exit the fossa cranii media. From this point, it enters the faossa pterygopalatina and branches extensively. Some branches will innervate the palatum durum (as the nervi nasopalatinus and palatinus major), but there are many other branches that provide no innervation to the palatum durum.
   E The foramen sphenopalatinum allows passage of the arteria sphenopalatina (of the arteria maxillaris) and the nervus nasopalatinus, and the rami nasales posteriores superiores mediales, and laterales. Although the nervus nasopalatinus innervates the palatum durum, it enters the cavitas oris via the foramen incisivum.

8. **D** The foramen mandibulae of the ramus is protected by the bony lingula mandibulae in a superoanterior position. The lingula mandibulae is an attachment site for the ligamentum sphenomandibulare.

   A The spinae mentales (spinae geni) are located in the internal genu of the mandibula and are for the attachment of the musculi geniohyoideus and genioglossus.
   B The hamulus pterygoideus is part of the lamina medialis proces-

sus pterygoidei of the os sphenoidale and is used for a lever around which the tensor veli palatini changes orientation from its vertical origin in the fossa scaphoidea of the os sphenoidale to reach the horizontal palatine aponeurosis palatina.
C The processus coronoideus of the mandibula is located in the superoanterior ramus mandibulae, but it is not associated with the foramen mandibulae. Instead, it provides the attachment site for the insertion for the musculus temporalis.
E The processus condylaris of the mandibula is located in the superoposterior ramus, but it is not associated with the foramen mandibulae. Instead, it provides the mandibular articulation of the articulatio temporomandibularis.

9. **B** The anteromedial floor of the canalis caroticus in the pars petrosa of the os temporale is "open" to the pars nasalis pharyngis through the foramen lacerum, although it is typically filled with cartilage after birth.

   A The foramen ovale of the os sphenoidale provides passage from the fossa cranii media to the fossa infratemporalis for the nervus mandibularis division of the nervus trigeminus (CN V_3), the nervus petrosus minor (CN IX), and the ramus accessorius arteriae meningeae mediae.
   C The foramen jugulare, located between the ossa temporale and occipitale, provides passage from the fossa cranii posterior to the deep prevertebral neck for the vena jugularis interna and the nervi glossopharyngeus, vagus, and accessorius.
   D The foramen spinosum of the os sphenoidale provides passage from the fossa infratemporalis to the fossa cranii media for the arteria meningea media, a branch of the arteria maxillaris, and the ramus meningeus (nervus spinosus).
   E The foramen mastoideum is an inconsistent passage for venae emissariae to pass through the os temporale. When present, it provides communication between the sinus sigmoideus and venae occipitales.

10. **C** The fossa cranii anterior is separated from the fossa cranii media by the posterior border of the ala minor of the os sphenoidale.

    A The lamina lateralis processus pterygoidei provides muscular attachment sites for both the musculi pterygoidei medialis and lateralis of the fossa infratemporalis. It is not located within the cranial vault.
    B The lamina perpendicularis of the os ethmoidale provides the superior half of the septum nasi and is in the cavitas nasi, not the cranial vault.
    D The pars petrosa of the os temporale separates the fossae cranii media and posterior. It provides attachment for the tentorium cerebelli and houses the auditory and vestibular infrastructure.
    E The crista frontalis of the os frontale is in the fossa cranii anterior, but it provides an anterior anchor for the falx cerebri, in the midline. It is not in a lateral position to allow for separation between fossae cranii anterior and media on both the right and left.

11. **A** The pterion, an H-shaped sutura between the ossa frontale, sphenoidale, temporale, and parietale, marks the location of the sulcus arteriae meningeae mediae on the internal surface of the lateral wall of the cranial vault.

    B The fossa hypophysialis, the central part of the sella turcica of the os sphenoidale, is a midline structure in the fossa cranii media.
    C The sulcus sinus sigmoidei begins just posterior to the processus mastoideus of the os temporale, at the location of the asterion. It is in the internal lateral wall of the cranial vault, but posterior to the pterion.
    D The meatus acusticus internus is centrally located in the pars petrosa of the os temporale, in the fossa cranii posterior.
    E The crista galli is a centrally located structure in the floor of the fossa cranii anterior.

12. **E** The foramen rotundum, a passageway for the nervus maxillaris division of the nervus trigeminus (CN V_2) to reach the fossa pterygopalatina, exits the fossa cranii media through the os sphenoidale.

    A The pars petrosa of the os temporale provides a posterolateral passage for the nervi facialis (CN VII) and vestibulocochlearis (CN VIII) via the meatus acusticus internus. It is located at the boundary between the fossae cranii media and posterior.
    B The os ethmoidale provides passage for the nervus ethmoidalis anterior and posterior of the nervus ophthalmicus division of the nervus trigeminus (CN V_1) via the foramina ethmoidalia anterius and posterius on the paries medialis of the orbita and passage of the nervi olfactorii from the cavitas nasi through the lamina cribrosa.
    C The os occipitale provides anterolateral passage for the nervus hypoglossus (CN XII) via the canalis nervi hypoglossi (anterior canalis condylaris). The canalis hypoglossus is located in the anterolateral wall of foramen magnum of the fossa cranii posterior.
    D The mandibula provides internal passage of the nervus alveolaris inferior branch of the nervus mandibularis division of the nervus trigeminus (CN V_3) via the foramen and canalis mandibulae.

13. **C** The majority of the palatum durum of the cavitas oris is formed from the union of the lamina horizontalis of the os palatinum with the processus palatinus of the maxilla.

    A The lamina medialis processus pterygoidei of the os sphenoidale forms the posterior lateral wall of the choana of the cavitas nasi, superior to the palatum durum. The hamulus pterygoideus, the inferior anterior part of the lamina media processus pterygoidei, forms a very small part of the posterolateral palatum durum.
    B The lamina perpendicularis of the os ethmoidale forms the superior half of the septum nasi, inside the cavitas nasi, above the palatum durum. At no point does it touch the lamina horizontalis of the os palatinum, although posterolateral parts of the os ethmoidale will create suture joints with the laminae perpendiculares of the os palatinum.
    D The pars squamosa of the os temporale is the lateral wall of the cranial vault. It is not associated with the palatum durum in any way.
    E The alae of the vomer articulate with the lamina horizontalis of the os palatinum but do so in the floor of the cavitas nasi as part of the septum nasi. They are not located in the cavitas oris and do not contribute to the inferior surface of the palatum durum.

Chapter 3 Vasculature & Lymphatics of the Head & Neck

14. **A** The arteria meningea media is a branch of the mandibular part of the arteria maxillaris that enters the skull through the foramen spinosum of the os sphenoidale to supply blood to the lateral part of the internal cranial vault and meninges.

    B The arteriae temporales profundae is a branch of the pterygoid part of the arteria maxillaris. It remains outside the skull between the external lateral cranial vault and the musculus temporalis and therefore does not traverse a foramen.
    C The arteria sphenopalatina is a terminal branch of the arteria maxillaris. From the fossa pterygopalatina, it passes through the foramen sphenopalatinum to enter the cavitas nasi.
    D The arteria carotis interna is not a branch of, and is substantially larger than, the arteria maxillaris. The arteria carotis interna enters the skull through the canalis caroticus of the os temporale to enter the fossa cranii media.
    E The arteria ophthalmica branches from the arteria carotis interna within the fossa cranii media. It runs anterior from the most rostral end of the arteria carotis interior, through the canalis opticus, to reach the orbita.

15. **B** The mandibular (bony/1st) part of the arteria maxillaris gives rise to the arteria alveolaris inferior. It enters the ramus mandibulae at the foramen mandibulae and subsequently gives off small branches that supply blood to the dentes molares, premolares, canini, and incisivi mandibulares and ends on the face as the arteria mentalis.

    A The arteria facialis is a direct branch of the arteria carotis externa, which wraps laterally around the corpus mandibulae but does not supply blood to any mandibular teeth. It does supply the cheeks, lips, nose, and anterior medial orbita.
    C The arteria lingualis is a direct branch of the arteria carotis externa, which is positioned medially to the mandibula and does not supply any mandibular teeth. It supplies the tongue and floor of the cavitas oris.

D The arteria sphenopalatina is a branch of the pterygopalatine part of the arteria maxillaris. It supplies the posterior superior cavitas nasi. Other branches of the pterygopalatine part of the arteria maxillaris are the arteriae alveolaris superior posterior and infraorbitalis. The arteria alveolaris superior posterior supplies the dentes molares maxillares; the arteria infraorbitalis gives off the middle superior alveolar artery to the dentes premolares maxillares and the arteria alveolaris superior anterior to the dentes incisivi maxillares.
E The arteria carotis interna does not have any branches external to the skull. It supplies blood to the anterior two-thirds of the brain and augments the blood supply to the posterior orbita.

16. **C** The arteria vertebralis is a major branch of the arteria subclavia, along with the arteria thoracica interna, truncus thyrocervicalis, and an inconsistent arteria dorsalis scapulae and/or truncus costocervicalis. The arteria vertebralis supplies blood to the posterior one-third of the brain and the paravertebral musculature of the neck.

    A The arteria carotis externa has eight branches that supply blood to the neck (arteria thyroidea superior), face (arteria facialis), tongue (arteria lingualis), upper and lower jaw (arteria maxillaris), caput laterale (arteria temporalis), ear (arteria auricularis posterior), back of the head (arteria occipitalis), and pharynx (arteria pharyngea ascendens). It does not give rise to the arteria vertebralis.
    B The arteria carotis communis has two major branches only, the arteriae carotides interna and externa.
    D, E The arcus aortae (D) gives rise to the truncus brachiocephalicus (E) on the right and the left arteria carotis communis and left arteria subclavia. The truncus brachiocephalicus subdivides into the right arteria subclavia and the right arteria carotis communis. The arteriae subclaviae on each side branch to give rise to the arteriae vertebrales.

17. **D** The venae ophthalmicae provide direct connections between the venae angulares and the sinus cavernosus via the orbita through the fissura orbitalis superior.

    A The plexus pterygoideus can serve as an intermediary between the vena angularis and the sinus cavernosus. To reach the plexus pterygoideus, blood must first travel through the vena profunda faciei or the infraorbital vein to the plexus pterygoideus, and subsequently through sphenoidal venae emissariae to reach the sinus cavernosus.
    B The vena retromandibularis has no direct connection to the sinus cavernosus. It provides a connection between the vena facialis (vena angularis) and the venae maxillaris and temporales superficiales, but to reach the sinus cavernosus, blood would once again need first to enter the plexus pterygoideus.
    C The vena lingualis has no direct connection to the sinus cavernosus. It drains into the vena retromandibularis, but infection would have to traverse multiple additional veins to reach the sinus cavernosus.
    E The truncus brachiocephalicus is an artery that supplies blood to the right side of the head and neck. Even the vena brachiocephalica, draining blood from the right (or left) side of the head and neck, does not provide direct a connection between the vena angularis and the sinus cavernosus.

18. **E** The truncus thyrocervicalis has four major branches: the arteriae thyroidea inferior, suprascapularis, transversa cervicis, and cervicalis ascendens. The ramus profundus of the arteria transversa cervicis (also called the arteria dorsalis scapulae) runs deep to the musculi rhomboidei. The ramus superficialis of the arteria transversa cervicis runs deep to the musculus trapezius.

    A The truncus brachiocephalicus is on the right side only. Compression of this structure, which is deep in the neck, is difficult; additionally, it would compromise the blood going to the right upper extremity, entire right side of the neck and face, and right side of the brain.
    B The arteria carotis communis has only two branches, the arteriae carotides interna and externa, which supply blood to the neck and head only.
    C The arteria thoracoacromialis supplies blood in the anterior part of the shoulder. The four typical branches are the rami pectorales, ramus deltoideus, rete acromiale, and ramus clavicularis. Although they may supply small amounts of blood to the superior edge of the musculus trapezius, they do not run near the musculi rhomboidei; therefore, compression will not arrest bleeding following this injury.
    D The truncus costocervicalis supplies blood to the musculi intercostales between the first two ribs, in a more lateral than posterior position. The plane of the injury is superficial to where this artery runs.

19. **C** The arteria cerebri media is a direct branch of the arteria carotis interna.

    A The arteria carotis communis has only two major branches: the arteriae carotides externa and interna.
    B The arteria carotis externa has eight major branches: the arteriae thyroidea superior, facialis, lingualis, maxillaris, temporalis superficialis, auricularis posterior, occipitalis, and pharyngea ascendens. These arteries and most of their branches stay external to the skull and do not supply any central nervous structures.
    D The arteria basilaris forms from the union of the left and right arteriae vertebrales. It supplies blood to the truncus encephali and cerebellum. It terminally bifurcates into the two arteriae cerebri posteriores that supply blood to the inferior lobus occipitalis.
    E The arteria meningea media is a branch of the arteria maxillaris in the fossa infratemporalis. It pierces the skull at the foramen spinosum and supplies blood to the dura in the lateral part of the skull.

20. **B** The sinus petrosi (both superior and inferior) drain the sinus cavernosi. The sinus petrosus superior then drains into the sinus sigmoideus; the sinus petrosus inferior drains into the vena jugularis interna.

    A The sinus rectus drains the sinus sagittalis inferior and venae internae cerebri and magna cerebri posteriorly to the confluens sinuum. There is no direct connection between the sinus cavernosi and the sinus rectus.
    C The vena jugularis externa drains the venae occipitalis, retromandibularis (from the face and the caput laterale via the vena temporalis superficialis), and auricularis posterior. There is no direct connection between the sinus cavernosi and the vena jugularis externa.
    D The plexus basilaris drains the inferior lobus frontalis and infralateral diencephalon to the sinus rectus. There is no direct connection between the sinus cavernosi and the plexus basilares.
    E The sinus maxillaris is an air sinus, rather than a venous dural sinus. It is connected to the cavitas nasi via the hiatus semilunaris of the meatus nasi medius.

21. **E** The nodi lymphoidei cervicales profundi drain lymph from the nodi lymphoidei occipitales, parotidei superficiales, and faciales, and submandibulares lymph nodes down to the jugulosubclavian venous junction, where the ductus thoracicus/lymphaticus dexter joins the cardiovascular system.

    A The nodi lymphoidei occipitales drain lymph from the posterior head to the nodi lymphoidei cervicales profundi. They collect lymph from regions significantly posterior to the ear.
    B The nodi lymphoidei faciales drain lymph from the anterior head into the nodi lymphoidei submandibulares. Subsequently, lymph drains into the nodi lymphoidei cervicales profundi and from there to the cardiovascular system via the ductus lymphaticus dexter/thoracicus.
    C The nuchal lymph nodes drain lymph from the posterior neck and posteroinferior head to the nodi lymphoidei cervicales profundi and from there into the cardiovascular system via the ductus lymphaticus dexter/thoracicus.
    D The laryngeotracheal lymph nodes drain lymph from the anterior neck and respiratory viscera to the nodi lymphoidei cervicales profundi and from there to the cardiovascular system via the ductus lymphaticus dexter/thoracicus.

Chapter 4 Neuroanatomy & Innervation of the Head & Neck

22. **A** The nervus abducens (CN VI) passes through the fissura orbitalis superior.

    B The foramen rotundum is for passage of the nervus maxillaris division of the nervus trigeminus (CN V_2).
    C The foramen ovale is for passage of the mandibular division of the nervus trigeminus (CN V_3).
    D The foramen infraorbitale is for passage of the nervus infraorbitalis (the largest branch of the nervus maxillaris division of the nervus trigeminus, CN V_2) to reach the surface of the face below the orbita.
    E The foramen spinosum is for passage of the arteria meningea media to enter the fossa cranii media of the skull.

23. **E** The nervus facialis (CN VII) innervates the musculus stapedius, the auris media muscle that modulates the motion of the stapes.

    A The nervus opticus (CN II) carries sensory innervation from the neural retina to the corpus geniculatum laterale of the thalamus.
    B The nervus oculomotorius (CN III) innervates the musculi recti , medialis, and inferior, and the musculus obliquus inferior (extraocular muscles), the musculi sphincter pupillae and ciliaris (intrinsic eye muscles), and musculus levator palpebrae superioris of the eyelids.
    C The nervus vestibulocochlearis (CN VIII) is responsible for transmitting sensory information for hearing and balance from the cochlea and vestibular apparatus, respectively, to the brain. It does not innervate any muscles.
    D The nervus trigeminus (CN V) innervates the musculus tensor tympani, the auris media muscle that is attached to the malleus, an arcus pharyngeus primus structure. The musculus tensor tympani acts to dampen sound.

24. **B** The nervus trochlearis innervates the musculus obliquus superior.

    A The musculus rectus lateralis is innervated by the nervus abducens (CN VI).
    C The musculus orbicularis oculi is innervated by the nervus facialis (CN VII).
    D The musculus rectus capitis lateralis is innervated by the ramus anterior of the C1 nervus spinalis.
    E The musculus dilator pupillae is innervated by the sympathetic root and the sympathetic components of the nervi ciliares brevis and longus.

25. **A** The nervus vagus (CN X) exits the fossa cranii posterior at the foramen jugulare.

    B The meatus acusticus interna is the fossa cranii posterior opening for the nervus facialis (CN VII), nervus vestibulocochlearis (CN VIII), and arteria labyrinthi.
    C The canalis condylaris of the os occipitale is the fossa cranii posterior exit for a vena emissaria connecting the sinus sigmoideus to the vena occipitalis.
    D The foramen magnum is the fossa cranii posterior entry for the arteriae vertebrales, pars spinalis of the nervus accessorius (CN XI), medulla oblongata of the truncus encephali, and cranial meninges (pia, arachnoid, and dura matres).
    E The foramen lacerum is mostly closed by cartilage in a living body, but it is traversed by the arteria carotis interna above and the tuba auditiva below. The only structures passing through the foramen lacerum are the autonomics of the ganglion cervicale superius that control vasoconstriction/vasodilation of the arteria carotis interna.

26. **C** The musculus hyoglossus is innervated by the nervus hypoglossus (CN XII), along with the musculus genioglossus, musculus styloglossus, and all intrinsic muscles of the tongue.

    A The ansa cervicalis, emerging from the rami anteriores of the C1–C3 spinal nerves, innervates the musculi sternohyoideus, sternothyroideus, and omohyoideus.
    B The nervus facialis (CN VII) innervates the musculus stapedius of the auris media, the musculus stylohyoideus and venter posterior musculi digastrici, and the musculi faciei.
    D The nervus mylohyoideus, a branch of the nervus mandibularis division of the nervus trigeminus (CN V_3), innervates the venter anterior musculi digastrici and musculus mylohyoideus.
    E The nervus laryngeus recurrens, a branch of the nervus vagus (CN X), controls the intrinsic muscles of the larynx, excluding the musculus cricothyroideus.

27. **D** Preganglionic parasympathetic fibers travel to the glandula parotidea via the nervus tympanicus, then the nervi petrosus minores both branches of the nervus glossopharyngeus (CN IX) to the ganglion oticum. Postganglionic fibers then travel with the nervus auriculotemporalis to the gland.

    A The chorda tympani, a branch of the nervus facialis (CN VII), carries preganglionic parasympathetic innervation to the ganglion submandibulare and subsequently to the glandulae submandibularis and sublingualis. It also carries taste innervation from the anterior two-thirds of the tongue.
    B The nervus petrosus major, a branch of the facial nerve (CN VII), carries preganglionic parasympathetic innervation to the ganglion pterygopalatinum. Branches of CN V_2 subsequently distribute postganglionic parasympathetic fibers to the glandula lacrimalis and small glands of the cavitas nasi, palatum, and pars nasalis pharyngis.
    C The nervus petrosus profundus arises from the plexus caroticus internus and carries postganglionic sympathetic innervation to the glandulae lacrimalis and small nasales, pars nasalis pharyngis, and palatum via branches of CN V_1 and CN V_2.
    E The nervus lingualis, a branch of the nervus mandibularis division of the nervus trigeminus (CN V_3), carries hitchhiking pre- and postganglionic parasympathetic innervation to the glandulae submandibulares and sublinguale. It also carries hitchhiking taste innervation from the anterior two-thirds of the tongue to the chorda tympani, as well as general somatic (touch, pain, and proprioception) innervation from the anterior tongue back to the nervus trigeminus.

28. **B** The C8 nervus spinalis exits the canalis vertebralis through the foramen intervertebrale below the C7 vertebra (therefore not E).

    A The C7 nervus spinalis exits the canalis vertebralis through the foramen intervertebrale above the C7 vertebra.
    C, D There is no C8 vertebra in the human columna vertebralis and therefore no C8 foramen transversarium.

29. **C** Slippage of the C3–C4 discus intervertebralis to the right would result in compression of the C4 nervus spinalis. This can present as changes in the C4 dermatome at the top of the shoulder.

    A An osteophyte in the C1–C2 foramen intervertebrale would start to compress the C2 nervus spinalis, which has a dermatome that correlates to the back of the head. Tingling and numbness here would be indicative of a problem at that level.
    B Compression of the nervus axillaris would present with the patient complaining of an inability to abduct his arm and articulatio glenohumeralis instability. Any cutaneous effects would relate to the superior lateral arm, not the top of the shoulder.
    D Referred pain from the splen can travel through the nervus phrenicus (C3–C5), but it normally would present as deep, throbbing or burning pain, rather than tingling or numbness, over the left shoulder.
    E Avulsion of the C6 nervus spinalis would result in the patient's inability to move or feel his thenar (thumb) region of the hand.

30. **D** The medulla oblongata develops from the myelencephalon, the caudal end of the rhombencephalon.

    A The pedunculus cerebri, for passage of the fibrae corticospinales, tractus corticopontinus, and corticobulbar tracts, is part of the mesencephalon, one of the primary vesicles of the developing brain.
    B The thalamus, a relay nucleus for most cortical input from subcortical regions, is part of the diencephalon. The diencephalon contains the thalamic structures, including the hypothalamus, epithalamus (including the glandula pinealis), subthalamus, and thalamus proper.
    C The pons is a synaptic and decussation site for the corticopontocerebellar tract. It is part of the metencephalon, which originally develops as the rostral end of the rhombencephalon.
    E The tectum mesencephali, made from the colliculi superior and inferior, is closely associated with visual tracking and hearing. It originally develops as part of the midbrain, or mesencephalon.

31. **E** The sulcus centralis separates the voluntary motor cortex from the conscious body sensation cortex on the ipsilateral side.

    A The sulcus calcarinus, located close to the falx cerebri, separates superior and inferior parts of the lobus occipitalis. This is the location of primary visual cortex. It is not associated with motor cortex.
    B The sulcus parietooccipitalis separates the lobus parietalis (conscious body sensation) from the lobus occipitalis (primary visual cortex). It is not associated with the motor cortex.
    C The sulcus lateralis separates the voluntary motor cortex of the lobus frontalis and the conscious body sensation cortex of the lobus parietalis from the lobus temporalis, which is the location of the primary auditory cortex and memory formation components of the limbic system.
    D The fissura longitudinalis separates the right and left hemispheria cerebri.

32. **A** The aqueductus cerebri can be blocked by the plexus choroideus of the ventriculus tertius; blockage results in noncommunicating hydrocephalus in an individual. There are no alternate CSF flow passages between the ventriculi tertius and quartus.

    B Blockage of CSF flow in the cisterna pontis in the spatium subarachnoideum will not cause hydrocephalus. There are numerous alternate routes for the CSF to flow to reach the granulationes arachnoideae. For example, CSF could flow from the cisterna pontis to the cisterna cerebellomedullaris, then the vermian cistern, cisterna ambiens, and finally reach the granulationes arachnoideae.
    C Blockage of CSF flow in the cisterna cerebellomedullaris in the spatium subarachnoideum will not cause hydrocephalus. There are numerous alternate routes for the CSF to flow to reach the granulationes arachnoideae. For example, CSF could flow from the cisterna cerebellomedullaris to the cisterna pontis, then the cisternae interpeduncularis and chiasmatica, and finally reach the granulationes arachnoideae.
    D The confluens sinuum is a dural venous sinus structure filled with deoxygenated blood. Blockage of this blood passage will not result in hydrocephalus.
    E The granulationes arachnoideae provide drainage of the CSF into the venous sinus system. Blockage here could result in a backup of CSF that may result in communicating hydrocephalus. However, all the internal CSF passages would remain open and unblocked.

Chapter 5 Face & Scalp

33. **C** The musculus orbicularis oris acts as an oral sphincter.

    A The musculus risorius retracts the corner of the mouth, pulling it posteriorly during grimacing and smiling.
    B The musculus depressor labii inferioris pulls the lower lip inferolaterally during pouting.
    D The musculus levator anguli oris raises the angle of the mouth during smirking and smiling, increasing the nasolabial furrow.
    E The orbital portion of the musculus orbicularis oculi acts as an orbital sphincter to close the eyelids voluntarily; the palpebral portion closes the eyes involuntarily.

34. **C** The musculus auricularis posterior is innervated by a branch of the nervus auricularis posterior, which comes off the nervus facialis before it enters the glandula parotidea.

    A The platysma is innervated by the ramus cervicalis of the nervus facialis.
    B The musculus zygomaticus major is innervated by the ramus zygomaticus of the nervus facialis.
    D, E The musculus risorius and buccinator are innervated by the rami buccales of the nervus facialis.

35. **B** The musculus buccinator is attached to the processus alveolares of the mandibula and maxilla, the raphe pterygomandibulare, and the lips.

    A The musculus depressor anguli oris is attached to the linea obliqua of the mandibula and the skin at the corner of the mouth.
    C The musculus levator labii superioris is attached to the processus frontalis and margo infraorbitalis of the maxilla and the skin of the upper lip.
    D The musculus zygomaticus minor is attached to the os zygomaticum and the upper lip.
    E The musculus mentalis is attached to the frenulum of the lower lip and the skin of the chin.

36. **D** Scalp infections can easily spread through the layer of loose areolar connective tissue.

    A–C, E Scalp infections are less likely to spread in the other four layers of the scalp.

37. **A** The arteria supraorbitalis is a terminal branch of the arteria ophthalmica, which arises from the arteria carotis interna.

    B The arteria facialis is a branch of the arteria carotis externa.
    C The arteria nasalis lateralis is a branch of the arteria facialis, which arises from the arteria carotis externa.
    D The arteria temporalis superficialis is a branch of the arteria carotis externa.
    E The arteria transversa faciei is a branch of the arteria temporalis superficialis, which arises from the arteria carotis externa.

38. **D** The nervus occipitalis major (ramus posterior of C2) is sensory to the occiput.

    A The nervus maxillares (CN V_2) is sensory to the midface.
    B The nervus transversus cervicalis (rami anteriores of C2–C3) is sensory to the anterior neck.
    C The nervus auricularis magnus (rami anteriores of C2–C3) is sensory to the lateral neck and earlobe.
    E The nervus facialis (CN VII) is motor to musculi faciei musculus stapedius, and venter posterior musculi digastrici and does not carry sensory information from the face or scalp.

39. **D** The vena facialis joins the anterior division of the vena retromandibularis to form the vena facialis communis.

    A The vena angularis drains into the vena facialis.
    B The vena jugularis anterior originates from superficial veins in the neck and drains to the terminal end of the vena jugularis externa or the vena subclavia.
    C The vena jugularis externa is formed from the posterior division of the vena retromandibularis and the vena auricularis posterior and drains to the vena subclavia.
    E The vena profunda faciei connects the vena facialis to the plexus pterygoideus.

40. **E** Branches of the nervus infraorbitalis (a branch of the nervus maxillaris division of the nervus trigeminus) are sensory to the upper lip.

    A The ramus alveolaris superior anterior (a branch of the nervi alveolares superiores [from CN V_2]) is sensory to the maxillary incisors and canines
    B The rami buccales of the nervus facialis are motor to some of the musculi faciei.
    C The nervus mentalis (a branch of the nervus mandibularis division of the nervus trigeminus) is sensory to the lower lip and chin.
    D The nervus supraorbitalis (a branch of the nervus ophthalmicus division of the nervus trigeminus [CN V_1]) is sensory to the upper eyelid and skin of the forehead.

Chapter 6 Fossae Temporalis, Infratemporalis, & Pterygopalatina

41. **D** The insertion (posterior attachment) of the musculus pterygoideus lateralis is the fovea pterygoidea and processus condylaris of the mandibula and the articulatio temporomandibularis (discus articularis).

    A The musculus pterygoideus medialis inserts (inferiorly attaches) to the tuberositas pterygoidea of the mandibula.
    B The musculus temporalis inserts (inferoanteriorly attaches) to the processus coronoideus of the mandibula.
    C The musculus masseter originates (superiorly attaches) from the corpus ossis zygomatici and the arcus zygomaticus made from the processus temporalis ossis zygomatici and the processus zygomati-

cus ossis temporalis.
E The musculus temporalis originates (superiorly attaches) on the lineae temporales of the lateral cranial vault.

42. **B** Much of the weight of the mandibula is supported by the ligamentum sphenomandibulare.

A The musculus mylohyoideus is located inferior to the mandibula and is attached to the corpus ossis hyoidei. It is not in a location where it can support the weight of the mandibula in normal anatomical position.
C The musculus digastricus is located inferior to the mandibula, but it is attached posteriorly to the incisura mastoidea of the os temporale. Only during extreme mandibular dislocation would the musculus digastricus play any role in supporting the weight of the mandibula, after many other structures have been compromised.
D The ligamentum pterygospinosum stretches between the lamina lateralis processus pterygoidei of the os sphenoidale and the spina ossis sphenoidalis. The ligament, if it is present, spans the incisura mandibulae, but it does not attach to the mandibula at any point and therefore cannot support its weight.
E The musculus buccinator is attached to the pars alveolaris of the mandibula and processus alveolaris of the maxilla. Its main function is to keep the cheek pressed against the teeth to avoid food accumulation in the vestibulum oris. The muscle fibers are oriented anteroposterior to facilitate that action, not resist the vertical pull of the weight of the mandibula.

43. **C** The location of musculus temporalis, between the lineae temporales of the ossa frontale and parietale, and temporal bones and the processus coronoideus mandibulae places part of the muscle posterior to the articulatio temporomandibularis (TMJ). This is the primary masticator that can retrude the mandibula.

A The location of the musculus masseter, between the arcus zygomaticus and the lateral ramus mandibulae, places the entire muscle anterior to the TMJ. It mainly elevates the mandibula, although it assists with protraction, side-to-side motion, and some retraction (from its caput profundum).
B The musculus pterygoideus medius, located vertically in the fossa infratemporalis between the medial side of the lamina lateralis processus pterygoidei ossis sphenoidalis and the medial ramus mandibulae, is placed anterior to the TMJ. It mainly elevates the mandibula.
D The musculus pterygoideus lateralis, located horizontally in the fossa infratemporalis between the lateral side of the lamina lateralis processus pterygoidei ossis sphenoidalis and the neck and fovea pterygoidea of the mandibula, is placed anterior to the TMJ. Its main action is to protrude the mandibula or assist in lateral motion for chewing.
E The musculus mylohyoideus is located in the floor of the cavitas oris between the sulcus mylohyoideus of the mandibula and the corpus ossis hyoidei and the mylohyoid raphe. The muscle is placed significantly anterior to the TMJ and is used to tighten the cavitas oris floor and protract the os hyoideum.

44. **A** The musculus pterygoideus lateralis protrudes the mandible and pulls it laterally for chewing.

B Tensing the palatum molle is performed by the musculi tensor veli palatini and levator veli palatini.
C Depression of the os sphenoidale is not possible.
D Elevation of the os hyoideum is performed by the musculi suprahyoidei—the musculi digastricus, geniohyoideus, stylohyoideus, and mylohyoideus. The musculus pterygoideus lateralis can only elevate the os hyoideum secondarily by first protruding the mandibula.
E Retraction of the mandibula is performed by the musculus temporalis, assisted by the musculus masseter.

45. **B** The ligamentum sphenomandibulare runs between the base of the os sphenoidale and the lingula mandibulae. It supports the weight of the mandibula and helps to prevent overprotraction of the mandibula.

A The musculus masseter has superior attachments on the body of the os zygomaticum and the anterior part of the arcus zygomaticus. The inferior attachment is the lateral ramus and the angulus mandibulae.
C The musculus temporalis has superior attachment along the linea temporales of the ossa frontale and parietale, and temporal bones and an inferior attachment on the processus coronoideus mandibulae.
D The ligamentum stylomandibulare runs between the processus styloideus of the os temporale and the ramus posterior and angulus mandibulae. Although it also prevents overprotraction, it does not attach to the lingula.
E The tuba auditiva has both partes ossea and cartilaginea. The pars ossea is supported within the pars petrosa ossis temporalis. The pars cartilaginea is not supported by a bony structure within the pars nasalis pharyngis but instead provides muscle attachment for some palatum molle muscles.

46. **D** The nervus buccalis, a branch of the nervus mandibularis, emerges between the two heads of the musculus pterygoideus lateralis.

A, B, E The nervus alveolaris inferior and the nervus lingualis emerge between the musculi pterygoidei medialis and lateralis.
C The nervi temporales profundi emerge superior to the caput superius of the musculus pterygoideus lateralis.

47. **B** The arteria tympanica inferior is a branch of the arteria pharyngea ascendens.

A, C The arteriae meningea media and auricularis profunda arteries are branches of the first (mandibular/bony) part of the arteria maxillaris.
D, E The arteria palatina descendens and the arteria canalis pterygoidei are branches of the third (pterygopalatine) part of the arteria maxillaris.

48. **B** The nervus auriculotemporalis, along with the nervi temporalis profundus posterior and the massetericus, is sensory to the TMJ.

A The nervus alveolaris inferior is sensory to the mandibular teeth, gingiva, and mucosa, as well as the chin and lower lip.
C The nervus lingualis is sensory to the tongue, floor of the mouth, and mandibular lingual gingiva.
D The nervus pterygoideus lateralis is motor to the musculus pterygoideus lateralis.
E The nervus buccalis is sensory to the mucosa on the inside of the cheek and the buccal gingiva and mucosa of the mandibular molars.

49. **E** The fissura pterygomaxillaris connects the fossa pterygopalatina with the fossa infratemporalis laterally. The arteria maxillaris and the posterior superior alveolar neurovascular bundle traverse this fissure.

A The canalis palatinus major connects the fossa pterygopalatina with the cavitas oris inferiorly.
B, D The canalis pterygoideus and foramen rotundum connect the fossa pterygopalatina with the fossa cranii media posteriorly.
C The foramen sphenopalatinum connects the fossa pterygopalatina with the cavitas nasi medially.

50. **C** The nervus petrosus major is a branch of the nervus facialis (CN VII) that carries preganglionic parasympathetic fibers to synapse in the ganglion pterygopalatinum. Before reaching the ganglion, it joins with the nervus petrosus profundus to form the nervus canalis pterygoidei (Vidian nerve).

A The nervus maxillaris (CN V_2) contains sensory fibers. Branches of the nervus maxillaris carry hitchhiking postganglionic parasympathetic fibers from the ganglion pterygopalatinum.
B The chorda tympani is a branch of the nervus facialis (CN VII) that carries preganglionic parasympathetic fibers to synapse in the ganglion submandibulare.
D The nervus petrosus minor is a branch of the nervus glossopharyngeus (CN IX) that carries preganglionic parasympathetic fibers to synapse in the ganglion oticum.
E The nervus petrosus profundus contains postsynaptic sympathetic fibers that join with the nervus petrosus major to form the nervus canalis pterygoidei (vidian nerve).

51. **A** The ala major ossis sphenoidalis is the roof of the fossa pterygopalatina.

B The posterior surface of the maxilla is the anterior wall of the fossa pterygopalatina.
C The lamina perpendicularis of the os palatinum is the medial wall of the fossa pterygopalatina.
D, E The os temporale and vomer do not form boundaries of the fossa pterygopalatina.

Chapter 7 Nose & Cavitas Nasi

52. **A** The os palatinum makes the posterior inferolateral walls and floor of the bony cavitas nasi. It helps to separate the cavitas oris from the cavitas nasi, just anterior to the palatum molle.

    B The os zygomaticum forms the cheek and the lateral wall of the sinus maxillaris, inferior to the orbit. It is located too laterally to help form the cavitas nasi.
    C The mandibula forms the lower jaw and the lateral walls of the cavitas oris. Although it is a midline bone, it is too inferior to help form the cavitas nasi.
    D The os parietale forms the posterolateral walls of the neurocranium, supporting the brain. The left and right ossa parietalia reach the midline to create the sutura sagittalis but are not associated with the cavitas nasi.
    E The os occipitale forms the bony roof of the pars nasalis pharyngis, but not the cavitas nasi.

53. **B** The meatus medius of the cavitas nasi, superior to the concha nasi inferior, allows for drainage of the sinus maxillaris (via the hiatus semilunaris), the cellulae ethmoidales anteriores and mediae, and the sinus frontalis (via the frontonasal duct).

    A The meatus inferior of the cavitas nasi, inferolateral to the concha nasi inferior, allows for drainage of the ductus nasolacrimalis from the orbita.
    C The meatus superior of the cavitas nasi allows for drainage of the cellulae ethmoidales posteriores.
    D The pars nasalis pharyngis, posterior to the cavitas nasi, allows for drainage of the tuba auditiva from the auris media.
    E The recessus sphenoethmoidalis, superior to the concha nasi superior, allows for drainage of the sinus sphenoidalis into the most superior part of the cavitas nasi.

54. **C** The arteria sphenopalatina has rami septales posteriores that anastomose with the rami septales anteriores arteriae ethmoidalis anterioris within Kiesselbach's area. It is a large branch of the arteria maxillaris that is found in the fossa infratemporalis.

    A The arteria alveolaris superior posterior supplies blood to the upper molars, but it remains in a lateral position. It is a branch of the arteria maxillaris that stays within the maxilla. It does not anastomose with the rami septales anteriores
    B The arteria meningea media supplies blood to the lateral dura mater, inside the cranial vault. It is also a branch of the arteria maxillaris, but it does not supply the viscerocranium.
    D The arteria pharyngea ascendens, a branch of the arteria carotis externa, supplies blood to the lateral pharynx and ascends toward the pars nasalis pharyngis. It does not reach into the cavitas nasi, nor does it anastomose with the rami septales anteriores.
    E The arteria tympanica anterior, also a branch of the arteria maxillaris, supplies blood to the anterior part of the auris media. It anastomoses with the arteria tympanica posterior off the arteria auricularis posterior and arteria canalis pterygoidei off the arteria carotis interna.

55. **D** The nervus nasopalatinus, a branch of the nervus maxillaris (CN V_2), innervates the posterior septum nasi, including the vomer.

    A The nervus olfactorius pierces the lamina cribrosa of the os ethmoidale and innervates the olfactory epithelium at the roof of the cavitas nasi.
    B The nervus ethmoidalis anterior, a branch of the nervus ophthalmicus (CN V_1), innervates the anterior medial and lateral walls of the cavitas nasi, including the anterior parts of the concha nasalis inferior.
    C The nervus palatinus major, a branch of the nervus maxillaris (CN V_2), innervates the palatum durum of the cavitas oris. It enters from a posterolateral position and runs anterior and medial.
    E The nervus alveolaris superior posterior, a branch of the nervus maxillaris (CN V_2), innervates the upper dentes molares inside the maxilla. It remains quite lateral and never reaches the nasal cavity.

56. **E** The sinus maxillaris is located immediately superior to the upper dentes molares. Complications with tooth extraction of the molars can result in problems within the sinus maxillaris.

    A The sinus frontalis is located superior to and between the orbitae. No teeth are closely associated with this sinus.
    B The cellulae ethmoidales are located superior to and between the orbitae. This bone is not associated with any teeth.
    C The cellulae mastoideae are located posterior and lateral to the auris media. Although they are close to the articulatio temporomandibularis, they are not closely associated with the dentes molares maxillares.
    D The sinus sphenoidalis is located posterior to the cellulae ethmoidales on the midline of the skull. The dentes molares are not associated with midline bones.

57. **D** The sinus sphenoidalis separates the cavitas nasi from the fossa hypophysialis, the location of the glandula pituitaria. This route provides the most direct access to the macroadenoma.

    A The sinus frontalis separates the cavitas nasi from the cranial vault, but only for access to the lobi frontales of the hemispheria cerebri. The glandula pituitaria is located in the fossa hypophysialis (sella turcica) of the os sphenoidale, significantly posterior the sinus frontalis.
    B The sinus ethmoidalis separates the cavitas nasi from the orbit and the fossa cranii anterior. Access to this space will still require access into the cranial vault via the canalis opticus or fissura orbitalis superior (of the os sphenoidale).
    C The sinus mastoideus is only connected to the cavitas nasi via the pars nasalis pharyngis and tuba auditiva. It would provide access from the auris media or externa to the posterior cranial vault, but it is exclusively contained within the os temporale.
    E The sinus maxillaris separates the cavitas nasi from the cavitas oris below and orbita above. Neither of these spaces will provide direct access to the glandula pituitaria.

Chapter 8 Cavitas Oris & Pharynx

58. **C** The venter posterior musculi digastrici is innervated by a small muscular branch of the nervus facialis, just after it exits the foramen stylomastoideum, before it enters the glandula parotidea to create the plexus intraparotideus.

    A The musculus mylohyoideus is innervated by a branch of the nervus mandibularis division of the nervus trigeminus, specifically, the nervus mylohyoideus.
    B The musculus hyoglossus is innervated by a small muscular branch of the nervus hypoglossus.
    D The musculus geniohyoideus is innervated by a small contribution from the C1 ramus anterior that joins the nervus hypoglossus as it traverses the lateral neck. It breaks from the nervus hypoglossus as it approaches the posterior border of the musculus mylohyoideus.
    E The musculus stylopharyngeus is not a true suprahyoid muscle. Furthermore, it is innervated by the nervus glossopharyngeus via a small muscular branch that breaks from the nerve along the superior border of the musculus constrictor pharyngis inferior.

59. **E** The nucleus ventralis posteromedialis receives somatosensory and special visceral sensory input from the head and neck. Input travels through the tractus trigeminothalamicus (central tegmental: taste), fibrae spinothalamicae (pain/temperature), and lemniscus medialis (face), and output goes to the gyrus postcentralis.

    A The nucleus ventralis anterior of the thalamus receives input from the globus pallidus and deep cerebellar nuclei and sends output to the gyrus precentralis of the hemispheria cerebri. It is a motor relay nucleus and is not associated with taste.
    B The nucleus dorsalis lateralis of the thalamus is closely associated

with memory formation. It receives input from the hippocampus and sends output to the gyrus cinguli of the hemispherium cerebri.
C The pulvinar thalami receives input from the thalami, parietalis, and occipitalis of the association cortex and sends output back to the same association cortex. It is an intercortical relay nucleus that is partially obsolete due to the telencephalic cortical connections of the splenium of the corpus callosum.
D The corpus geniculatum mediale deals with auditory information as a relay between the truncus encephali and the primary auditory cortex in the posterior gyrus temporalis superior. Most of the input comes from the colliculus inferior, lemniscus lateralis, or nucleus olivaris superior, and the output goes through the radiationes acusticae of the crus posterius of the capsula interna to the lobus temporalis.

60. **A** The musculus tensor veli palatini is connected to the anterolateral pars cartilaginea tubae auditivae and the aponeurosis palatina via the hamulus pterygoideus. It flattens the palatum molle and opens the tuba auditiva.

B The musculus palatoglossus is connected to the aponeurosis palatina and the lateral dorsal tongue (intrinsic muscles). It elevates the tongue and depresses the palatum molle. It is not connected to the tuba auditiva.
C The musculus palatopharyngeus is connected to the aponeurosis palatina and the lateral pharynx and cartilago thyroidea. It elevates the pharynx and depresses the palatum molle. It is also not connected to the tuba auditiva.
D The musculus tensor tympani is connected to the tuba auditiva tube within the pars petrosa ossis temporalis. It runs posterolaterally to insert into the malleus. It stiffens the membrana tympanica to reduce the transmission of sound. It is not associated with the palatum molle.
E The musculus constrictor pharyngis superior has a variety of attachments, including both bony and fibrous, but no cartilaginous attachments. It originates on the hamulus pterygoideus and linea mylohyoidea (bony) and the raphe pterygomandibularis and lateral tongue (fibrous). It inserts into the tuberculum pharyngeum of the pars basilaris ossis occipitalis. It is not associated with the palatum molle.

61. **B** The tonsilla lingualis is located on the dorsal radix linguae, closely associated with the epiglottis of the larynx. This midline tonsil completes the inferior extent of the anulus lymphoideus pharyngis.

A The tonsillae tubariae are associated with the tuba auditiva of the pars nasalis pharyngis. They are located posterolateral within the space and are not closely related to the midline epiglottis.
C The tonsilla pharyngea is a midline structure located between the right and left tubae auditivae of the pars nasalis pharyngis. It is adjacent to the left and right tonsillae tubariae and completes the superior extent of the anulus lymphoideus pharyngis, but it is not closely associated with the epiglottis.
D The tonsillae palatinae are located between the arci palatoglossus (anterior) and palatopharyngealis (posterior) of the pars oralis pharyngis. These two laterally located lymph structures are closely associated with the lateral tongue, close to but not immediately adjacent to the epiglottis.
E The tonsilla adenoidea is another name for the tonsilla pharyngea of the pars nasalis pharyngis. It is the superiormost part of the anulus lymphoideus pharyngis.

62. **D** Dentinum makes up the majority of the tooth volume. It is deep to the enamelum and cementum and surrounds the cavitas pulparis.

A The periodontal ligament connects the cementum to the alveolar bone.
B Cementum covers the radices of the teeth (enamelum covers the coronae). The cementum and enamelum meet at the cementoenamel junction, located at the cervical margin of the tooth.
C The pulpa is located in the cavitas pulparis at the center of the tooth. The cavitas pulparis is surrounded by dentineum, enamelum, and cementum.
E The radices dentum are embedded in the alveolar bone of the mandibula and maxilla.

63. **D** The 1st dentes molares erupt at 6 to 8 years of age and are commonly called the “6-year molars.”

A The dentes canini erupt at 9 to 14 years of age.
B The 1st dentes premolares erupt at 9 to 13 years of age.
C The 2nd dentes premolares erupt at 11 to 14 years of age.
E The 2nd dentes molares erupt at 10 to 14 years of age.

64. **E** The ganglion submandibulare provides postganglionic parasympathetic fibers for the glandulae submandibularis and sublingualis.

A The ganglion cervicis superius provides postganglionic sympathetic fibers (not parasympathetic) for the head.
B The ganglion pterygopalatinum provides postganglionic parasympathetic fibers for the palatum, nasal mucosa, and glandulae lacrimales.
C The ganglion ciliare provides postganglionic parasympathetic fibers for the eye.
D The ganglion oticum provides postganglionic parasympathetic fibers for the glandula parotidea.

65. **B** The glandula parotidea is a serous gland.

A, C The glandula parotidea does not produce mucous secretions. The glandula submandibularis produces both mucous and serous secretions. The glandula sublingualis is a mixed gland with predominantly mucous secretions.

66. **A** Infections from the dentes molares maxillares and mandibulares can spread to the spatia peripharyngea (spatia retropharyngeale and parapharyngeale). They can also spread to the buccal space or submandibular, sublingual, or masticator spaces (mandibular molars only).

B Infections from the dentes canini maxillares can spread to the infraorbital space.
C Infections from the dentes premolares mandibulares can spread to the buccal and sublingual spaces.
D, E Infections from the dentes canini and incisivi mandibulares can spread to the submental space.

67. **B** The submandibular space is inferior to the linea mylohyoidea, superior to the os hyoideum, inferior and lateral to the musculus mylohyoideus, and medial to the superficial fascia and skin.

A The sublingual space is inferior to the mucosa of the oral floor, superior to the musculus mylohyoideus, lateral to the tongue, and medial to the mandibula.
C The masticator space is anterior to the ligamentum stylomandibulare, medial to the fascia cervicalis, and inferior to the roof of the fossa infratemporalis and the origin of the musculus temporalis.
D The tonsillar space is posterior to the musculus palatoglossus, anterior to the musculus palatopharyngeus, lateral to the mucosa of the pars oralis pharyngis, and medial to the fascia pharyngobasilaris.
E The parotid space is posterior to the ramus mandibulae and ligamentum stylomandibulare, anterior to the musculus sternocleidomastoideus, lateral to the processus styloideus and attaching muscles, and medial to the skin.

Chapter 9 Orbita & Eye

68. **D** The arteria ophthalmica (E) runs through the canalis opticus and supplies blood to the orbita; it is a branch of the arteria carotis interna after it has entered the fossa cranii media.

A The arteria meningea media is a superior branch of the mandibular (bony/1st) part of the arteria maxillaris that enters the skull through the foramen spinosum of the os sphenoidale to supply blood to the lateral part of the internal cranial vault.
B The arteria temporalis profunda stays outside the skull and runs between the external lateral cranial vault and the musculus temporalis. It is a branch of the pterygoid (muscular/2nd) part of the arteria maxillaris that never runs through a foramen.
C The arteria sphenopalatina is the anteromedial terminal branch of the arteria maxillaris that enters the skull at the fissura pterygomaxillaris to access the posterolateral cavitas nasi. It runs medially through the foramen sphenopalatinum to reach the cavitas nasi.

69. **E** The musculus obliquus superior is innervated by the nervus trochlearis. The muscle resides along the superior medial wall of the orbita and runs through a small fascial pulley to insert into the superior aspect of the bulbus oculi.

    A The venter anterior musculi digastrici is innervated by a nervus mylohyoideus, a branch of the nervus mandibularis division of the nervus trigeminus. It is in the suprahyoid region of the neck, not the orbita.
    B The musculus rectus lateralis is innervated by the nervus abducens. It resides lateral to the bulbus oculi, inside the bony orbit.
    C The musculus obliquus inferior is innervated by the ramus inferior of the nervus oculomotorius. The muscle resides inferior to the bulbus oculi, inside the bony orbit.
    D The musculus rectus capitis lateralis is innervated by the ramus anterior of the C1 nervus spinalis. It is in the paravertebral space, inferior to the skull, between the os occipitale and the 1st cervical vertebra.

70. **A** The fissura orbitalis superior is for the passage of the rami superior and inferior of the nervus oculomotorius (CN III), in addition to all parts of the nervus ophthalmicus division of the nervus trigeminus (CN V_1), nervus trochlearis (CN IV), nervus abducens (CN VI), and vena ophthalmica superior.

    B The foramen rotundum is for passage of the nervus maxillaris division of the nervus trigeminus (CN V_2).
    C The foramen ovale is for passage of the nervus mandibularis division of the nervus trigeminus (CN V_3).
    D The foramen infraorbitale is for passage of the largest branch of the nervus maxillaris division of the nervus trigeminus (CN V_2) to reach the surface of the skull in the upper jaw.
    E The foramen spinosum is for passage of the arteria meningea media to enter the fossa cranii media.

71. **B** The bipolar cell, located in the stratum nucleare internum, is the intermediate neuron (sensory) between the photoreceptor cells and the retinal ganglion cells.

    A The horizontal cell, located in the outer region of the stratum nucleare internum, interconnects the photoreceptors to spread or collect visual signals. It does not connect to the retinal ganglion cells.
    C The amacrine cell, located in the inner region of the stratum nucleare internum, interconnects the bipolar cells and the retinal ganglion cells to start to process visual signals. It does not connect to the photoreceptor cells.
    D The Purkinje cell, located in the cortical layer of the cerebellum, is the output neuron that connects the cortex cerebelli to the deep cerebellar nuclei. It is not associated with the retina.
    E The Müller cell, located in the stratum nucleare internum, is the main glial support cell of the retina. Although its cell body is located in this layer, its peripheral and central processes make the inner and outer limiting membranes. It does not connect to either photoreceptor cells or retinal ganglion cells.

72. **C** The chiasma opticum is where nasal retinal information (from the temporal field) from both eyes crosses to the contralateral side. It is located anterosuperior to the glandula pituitaria. A problem here would produce tunnel vision; it also can be associated with pituitary problems such as weight gain and reproductive cycle changes.

    A The nervus opticus sends information from a single bulbus oculi to both right and left corpora geniculata lateralia. A problem here would likely present with orbital problems, such as blindness in one eye, paralysis of the extraocular muscles, and dry eye. It would not be associated with weight gain or a change in the menstrual cycle.
    B The tractus opticus sends information from both eyes, from a single visual field (right or left) to the ipsilateral corpus geniculatum laterale. A problem here would present with blindness in either the right or left visual field (contralateral homonymus hemianopia). It would not be associated with weight gain or a change in the menstrual cycle.
    D The pars retrolentiformis capsulae internae is the location of the radiationes opticae that send information from the corpus geniculatum laterale to the primary visual cortex (in the sulcus calcarinus of the lobus occipitalis). A problem here would result in a modified form of hemianopia that has a specific subquadrant missing from the patient's visual space (contralateral homonymus quadrantanopia). It would not be associated with weight gain or a change in the menstrual cycle.
    E The splenium corporis callosi interconnects the right and left posterior lobi parietales, posterior lobi temporales, and lobi occipitales. It allows for cortical communication between the two hemispheres. Problems here would be auditory, visual, memory, and somatosensory. It would not be associated with weight gain or a change in the menstrual cycle.

Chapter 10 Ear

73. **B** The arteria temporalis superficialis has rami auriculares anteriores that supply blood to the anterior auris externa.

    A The arteria transversa faciei runs anterior, immediately inferior to the arcus zygomaticus. It supplies blood to the deep musculi faciei and the lateral cheek. It does not run posteriorly toward the ear.
    C The arteria sphenopalatina is a terminal branch of the arteria maxillaris that supplies blood to the medial and lateral part of the cavitas nasi. It does not run posteriorly or superficially toward the ear.
    D The arteria carotis interna enters the skull through the canalis caroticum of the os temporale to access the fossa cranii media from below. It supplies blood to the anterior brain and has no branches that supply the auris externa.
    E The arteria occipitale is a posterior branch of the arteria carotis externa. It runs deep to the musculus sternocleidomastoideus and supplies blood to the posterior scalp and musculus occipitalis.

74. **B** The nervus facialis carries taste fibers in its chorda tympani branch. This branch of the nervus facialis traverses the cavitas tympani, just medial to the colum mallei and the membrana tympanica.

    A The nervus trigeminus only carries hitchhiking taste fibers that originate in the nervus facialis. The branch that carries these taste fibers is the nervus lingualis, which is joined by the chorda tympani inferior to the skull as they both approach the cavitas oris from a posterior direction.
    C The nervus vestibulocochlearis does not carry any taste fibers. It carries other special somatic sensory fibers to the cochlea and vestibular apparatus, but these terminate at the auris interna and do not enter the cavitas tympani.
    D The nervus glossopharyngeus carries taste fibers, but they reside within the rami pharyngei that join the main trunk of the nerve and enter the skull through the foramen jugulare. The nervus tympanicus, which also traverses the air space of the cavitas tympani, is a branch of the nervus glossopharyngeus, but it only carries general somatic afferent (pain, touch, and proprioception) from the auris media and visceromotor fibers to the ganglion oticum to drive secretion in the glandula parotidea.
    E The nervus vagus carries taste fibers from the radix linguae, epiglottis, and pharynx, but they reside in rami pharyngei that join the main trunk of the nerve and enter the skull through the foramen jugulare.

75. **C** The stapes of the cavitas tympani has a footplate that fits neatly into the fenestra vestibuli of the medial wall of the cavitas tympani. It is used to transmit sound waves, detected by the membrana tympanica, to the auris interna.

    A The malleus of the cavitas tympani is attached to the membrana tympanica via its manubrium. Although it is in the cavitas tympani, it is not physically attached to the medial wall or the auris interna.
    B The os pisiforme is a carpal bone located in the proximal anteromedial wrist, adjacent to the head of the ulna. It is not located in the auris media region of the os temporale of the skull.
    D The os naviculare of the foot supports the medial side of the talus and transmits forces into the three ossa cuneiforma of the foot. It is not located in the auris media.
    E The incus of the cavitas tympani is supported between the malleus and stapes (and by other ligaments of the cavitas tympani). It is not physically attached to the medial wall or the auris interna.

76. **D** The meatus acusticus internus provides a passage for the nervus vestibulocochlearis to exit the fossa cranii posterior and reach the inner ear. The meatus acusticus internus also transmits the nervus facialis and the arteria labyrinthina.

A The hiatus canalis nervi petrosi majoris provides a passage for the nervus petrosus major (a branch of the nervus facialis) and the arteria petrosa superficialis to exit the pars petrosa of the os temporale and enter the fossa cranii media as they course toward the foramen lacerum.
B The meatus acusticus externus provides a passage for sound waves to enter the skull and reach the membrana tympanica, located within the os temporale. It does not provide access to the fossa cranii posterior.
C The canaliculus mastoideus provides passage for the ramus auricularis of the nervus vagus to enter the meatus acusticus externus from an inferior direction. It does not provide access to the fossa cranii posterior.
E The foramen stylomastoideum provides passage for the nervus facialis and arteria stylomastoidea to exit the pars petrosa of the os temporale on the inferior aspect of the skull.

77. **E** The left canalis semicircularis posterior aligns with a 45-degree plane offset from the median (posterior-anterior) axis of the head. It lies in a plane parallel to the right canalis semicircularis anterior.

A The right canalis semicircularis posterior aligns with a 45-degree plane offset from the median (anterior-posterior) axis of the head. It lies in a plane parallel to the left canalis semicircularis anterior.
B The right canalis semicircularis lateralis aligns with a 30-degree plane offset from the horizontal axis of the head. It lies in the exact same (parallel) plane as the left canalis semicircularis lateralis.
C The left canalis semicircularis anterior aligns with a 45-degree plane offset from the median (anterior-posterior) axis of the head. It lies in a plane parallel to the right canalis semicircularis posterior.
D The left canalis semicircularis lateralis aligns with a 30-degree plane offset from the horizontal axis of the head. It lies in the exact same (parallel) plane as the right canalis semicircularis lateralis.

78. **A** The lamina basilaris stretches between the modiolus and ligamentum spirale and therefore lies between the endolympha and perilympha. It physically supports the hair cells of the cochlear.

B The ligamentum spirale underlies the stria vascularis of the ductus cochlearis. It supports the secretory stria, but it is not physically attached to the hair cells and does not come into contact with perilympha.
C The membrana vestibularis stretches between the modiolus and the ligamentum spirale and also separates endolympha and perilympha. However, it is not a support structure of the hair cells and is not closely associated with sound detection.
D The membrana tectoria covers (supports) the stereocilia of the hair cells of the ductus cochlearis. It is completely enclosed within the ductus cochlearis and does not separate perilympha from endolympha.
E The helicotrema is a perilymphatic passage between the scala vestibuli and scala tympani. It does not separate endolympha from perilympha and is not associated with the hair cells.

79. **C** The ganglion spirale contains the cell bodies whose peripheral processes synapse with the inner hair cells and whose central processes are the main synaptic input for the nuclei cochleares. Without this input, no sound perception can be detected, so no sound could be localized.

A The nuclei vestibulares are critical for the perception of linear or angular acceleration changes of the head due to motion. None of these systems are critical for the localization of sound in auditory space (anterior, posterior, right, or left), which can be accomplished in a stationary head.
B The musculus tensor tympani contracts to change the tuning of the membrana tympanica. Although it can be used to augment (or depress) the perception of sound, it is not used to localize sound.
D The corpus geniculatum laterale is one of the synaptic targets of the tractus opticus. It deals exclusively with visual information, which is not necessary for the localization of sound.
E The lemniscus medialis is the midbrain tegmental pathway connecting the posterior column nuclei (gracilis and cuneatus) to the nuclei ventroposterolateralis and ventroposteromedialis of the thalamus. This pathway is for perception of touch and conscious proprioception and is not necessary for the localization of sound.

Chapter 11 Bones, Ligaments, & Muscles of the Neck

80. **B** The musculus geniohyoideus draws the os hyoideum anteriorly and is innervated by the ramus anterior of the C1 nervus spinalis carried by the nervus hypoglossus.

A The musculus mylohyoideus draws the os hyoideum anteriorly, but it is innervated by the nervus mylohyoideus, a branch of the nervus mandibularis division of the nervus trigeminus (CN V_3).
C The musculus stylohyoideus elevates the os hyoideum (and helps with posterior motion) and is innervated by the nervus facialis (CN VII).
D The musculus omohyoideus depresses the hyoid and fixes it in place. It is innervated by the ansa cervicalis, the C1–C3 rami anteriores that innervate most musculi infrahyoidei in the anterior neck.
E The musculus sternohyoideus depresses the os hyoideum and fixes it in place. It is also innervated by the ansa cervicalis, the C1–C3 rami anteriores.

81. **E** The musculus sternocleidomastoideus of the neck rotates the head to the contralateral (opposite) side.

A, B The musculi rectus capitis posterior major and longissimus capitis extend the head and rotate it to the ipsilateral (same) side.
C The musculi rectus capitis lateralis flexes the head at the articulatio atlantooccipitalis anteriorly and laterally to the ipsilateral side.
D The musculi splenius capitis extends the cervical spine and head, as well as flexes and rotates the head to the ipsilateral side.

82. **A** The musculus splenius cervicis originates (proximally attaches) to the processus spinosi of T3–T6.

B The musculi levatores costarum longi originate (inferiorly attach) to the processus transversi of the C7–T11 vertebrae.
C The musculus serratus posterior superior originates (proximally attaches) on the ligamentum nuchae and the processus spinosi of the C7–T3 vertebrae. It does not extend as inferior as the T6 vertebra.
D The musculus iliocostalis thoracis originates (proximally attaches) on the crista iliaca, os sacrum, fascia thoracolumbalis, and inferior ribs.
E The musculus longus colli originates (inferiorly attaches) to the anterior surfaces of the T1–T3 vertebrae in the prevertebral space.

83. **C** The musculus geniohyoideus of the suprahyoid group is innervated by the ramus anterior of the C1 nervus spinalis.

A The nervus mylohyoideus, a branch of the nervus mandibularis division of the nervus trigeminus (CN V_3), innervates the musculus mylohyoideus and venter anterior musculi digastrici of the suprahyoid group, but it does not reach deeper than the musculus mylohyoideus.
B The nervus facialis (CN VII) innervates the musculi faciei, the venter posterior musculi digastrici and musculus stylohyoideus of the suprahyoid group, and the musculus stapedius. The branches that reach far enough anterior (rami marginalis mandibularis and cervicalis) do not reach deeper than the thin musculi faciei.
D The nervus alveolaris inferior (of CN V_3) is a purely sensory nerve that travels the length of the corpus mandibulae to reach the foramen mentale and provide sensory perception from the mandibular teeth and the mental region of the face. It does not innervate any muscles.

E The nervus hypoglossus (CN XII) carries innervation to the intrinsic and most extrinsic muscles of the tongue (musculi genioglossus, hyoglossus, and styloglossus, not palatoglossus). It provides a route for the ventral ramus of the C1 nervus spinalis to reach the musculus geniohyoideus but does not innervate any of the musculi suprahyoidei.

Chapter 12 Neurovascular Topography of the Neck

84. **A** The valleculae epiglotticae are the spaces between the tongue and the epiglottis that allow nursing infants to be able to breathe (through their nose) and nurse simultaneously. They are at the superior end of a gutter that extends through the recessus piriformes to reach the pars laryngea pharyngis and the oesophagus.

    B The recessus piriformes are lateral to the epiglottis, superior and lateral to the cartilago cricoidea. They are continuous with the valleculae epiglotticae superiorly and the oesophagus inferiorly.
    C The rima glottidis is the aperture between the left and right ligamenta vocalia and plicae vocales. This is a midline structure that lies posterior and inferior to the epiglottis.
    D The foramen caecum is a small pit at the boundary of the anterior and posterior tongue that is the embryological remnant of the thyroglossal duct. It is located on the midline, posterior to the papillae vallatae.
    E The fossa tonsillaris is occupied by the tonsilla palatina, located between the arcus palatoglossus and palatopharyngeus. This lies anterior to the epiglottis, lateral to the tongue.

85. **B** The musculus scalenus medius inserts (distally attaches) into costa I posterior to the sulcus arteriae subclaviae.

    A The superomedial angle of the scapula provides the insertion (distal attachment) for the musculus levator scapulae. Lateral to this position on the scapula, the musculus omohyoideus has an origin (proximal attachment). The msuculus scalenus medius is not connected to the scapula.
    C The costa II provides the insertion (distal attachment) for the musculus scalenus posterior, which shares some of the same origin (proximal attachment) as the musculus scalenus medius, but the muscle fibers run in a slightly different direction. The musculus scalenus medius is not connected to costa II.
    D The pars basilaris ossis occipitalis provides the insertion (distal attachment) for a variety of prevertebral muscles, including the musculi longus capitis, rectus capitis anterior, rectus capitis lateralis, and constrictor pharyngis superior. Although some of these muscles share the same origin (proximal attachment) as the musculus scalenus medius, they run in completely different directions. The musculus scalenus medius is not connected to the basal skull.
    E The manubrium sterni is the origin (proximal attachment) of the musculi sternocleidomastoideus and pectoralis major. Although the musculi sternocleidomastoideus is very close and runs in a similar direction to the musculus scalenus medius, they have very different functions. The musculus scalenus medius is not attached to the manubrium sterni.

86. **D** The occipital triangle provides the best access to the nervus accessorius as it travels superficial to the musculus levator scapulae as it crosses the musculi sternocleidomastoideus and trapezius in the trigonum cervicale posterius. It also contains some of the nervi supraclaviculares and the nervi occipitales of the neck.

    A The trigonum submandibulare of the anterior neck contains the nervus hypoglossus, branches of the C1 ramus anterior, and branches of the nervus mandibularis division of the nervus trigeminus. It is located too far anterior to provide access to the nervus accessorius.
    B The trigonum musculare of the anterior neck contains nervi laryngei branches of the nervus vagus and most of the ansa cervicalis (C1–C3 anterior rami). It is located too far anterior to provide access to the nervus accessorius.
    C The trigonum caroticum of the anterior neck lies just anterior to the middle part of the musculus sternocleidomastoideus. In this triangle, the ansa cervicalis and nervus vagus are the most prominent nervous structures. There are rami sinus carotici of the nervus glossopharyngeus as well, but these are usually quite small.
    E The trigonum omoclaviculare, located in the posterior triangle of the neck, has no nervous structures located in it. Deep to the triangle, it is possible to access the plexus brachialis, but not the nervus accessorius.

87. **C** The nervus vagus travels the entire length of the vagina carotica, running parallel to the arteriae carotides communis and interna and the vena jugularis interna.

    A The nervus facialis and its branches remain in the head for the most part. There is a ramus cervicalis of the nervus facialis that drops into the neck to innervate the platysma, superficial to the vagina carotica. No other branches come close to the vagina carotica.
    B, D, E The nervi glossopharyngeus, accessorius, and hypoglossus pass tangentially (anteroinferior) through the most superior part of the vagina carotica. The nervus glossopharyngeus contributes to the plexus pharyngeus and has branches innervating the musculus stylopharyngeus and the glomus caroticum. The nervus accessorius innervates the musculi sternocleidomastoideus and trapezius. The nervus hypoglossus innervates the intrinsic and extrinsic tongue muscles (except the musculus palatoglossus).

88. **D** The spatium parapharyngeum will allow infections from the cavitas oris to drain, via gravitational abscess, into the mediastinum, causing mediastinitis.

    A The sinus cavernosus is accessible from the spatuium parapharyngeum, but it lies superior to the parapharyngeal space associated with the cavitas oris. An inferior bacterial spread (gravitational abscess) would not move to this location.
    B The lung is somewhat isolated from the spatuium parapharyngeum due to the nature of the pleura of the cavitas thoracis. Bacterial infection would need to traverse this barrier to spread to the lungs.
    C The gaster is isolated from the spatuium parapharyngeum due to the nature of the peritoneum of the cavitas abdominalis. Bacterial infections would need to traverse this barrier to spread to the stomach.
    E The spatium subarachnoideum is accessible from the spatium parapharyngeum, but it lies superior to the spatium parapharyngeum associated with the cavitas oris. An inferior bacterial spread (gravitational abscess) would not move to this location.

89. **E** The C1 ramus anterior is the main contributor to the radix superior of the ansa cervicalis. It breaks away from the nervus hypoglossus, where it is temporarily carried, in such a way as it appears that the radix superior of the ansa cervicalis is a large branch of the nervus hypoglossus.

    A The nervus vagus has branches that contribute to the plexus pharyngeus, nervus laryngeus superior, and nervus laryngeus recurrens. All of these branches are significantly deeper than the ansa cervicalis.
    B The nervus hypoglossus seems to have a large contribution to the radix superior of the ansa cervicalis, but it is really just the ramus anterior of the C1 nervus spinalis that breaks away to create the radix superior. The branches of the nervus hypoglossus innervate the muscles of the tongue only.
    C The C3 ramus anterior contributes to the radix inferior of the ansa cervicalis, as well as the nervi phrenicus, supraclaviculares, transversus cervicalis, and auricularis magnus. Most branches run either significantly inferior or posterior to the ansa cervicalis.
    D The C2 ramus posterior contributes to the innervation of the muscles of the regio cervicalis posterior and the nervus occipitalis major. It is a posterior nerve that has no branches that run anteriorly toward the ansa cervicalis.

90. **A** The vena transversa cervicis drains anteriorly in the occipital triangle to reach the vena jugularis externa. It collects blood from the retroauricular vein and venae occipitales as it moves across the lateral neck.

    B The vena thyroidea inferior drains inferiorly directly into to the vena brachiocephalica. It can be accompanied by a small arteria thyroidea ima, but it is not associated with the vena jugularis externa.
    C The plexus pterygoideus drains blood from the fossa infratemporalis through the vena maxillaris to reach the vena retromandibularis. From here, blood can flow anterior into a vena facialis communis

(vena facialis and anterior division of the vena retromandibularis) or posteriorly into the vena jugularis externa. There are no direct connections between the plexus pterygoideus and the vena jugularis externa.
D The vena facialis drains posteroinferiorly along the corpus mandibulae and meets the anterior division of the vena retromandibularis. From here, blood drains through a vena facialis communis to reach the vena jugularis interna. It is only through increased venous pressure that blood might flow superiorly through the vena retromandibularis to the vena jugularis externa.
E The vena lingualis drains blood from the floor of the cavitas oris and meets the vena facialis just prior to becoming the vena facialis communis. From here, blood typically drains into the vena jugularis interna.

Chapter 13 Larynx & Glandula Thyroidea

91. **A** The base of the cartilago thyroidea provides an attachment for the midline of the cartilago epiglottica via the ligamentum thyroepiglotticum. It is at the posterior union of the two thyroid laminae that this ligament attaches.

    B The cartilago cricoidea physically supports the two cartilagines arytenoideae and maintains two articulationes cricothyroideae in a posterolateral position with the cornu inferius of the cartilago thyroidea. There are no direct connections between the cartilago cricoidea and the epiglottis.
    C The cartilagines arytenoideae rest on the faciei articulares arytenoideae in a lateral position on the superior posterior surface of the cartilago cricoidea. The cartilagines arytenoideae physically support the cartilagines corniculatae at their apices.
    D The cartilagines corniculata rest on the superior medial apices of the cartilagines arytenoideae, in a slightly lateral and posterior position within the larynx. The epiglottis is attached at an anterior inferior position, diagonally opposite the position of these cartilages.
    E The tracheal cartilage rings occupy anterior and lateral positions inferior to the larynx. They reside inferior to the cartilagines cricoideae and thyroideae, significantly inferior to the anterior midline attachment of the cartilago epiglottica.

92. **A** The musculus cricoarytenoideus posterior rotates the cartilago arytenoidea outward and toward the side to abduct the plicae vocales and open the rima glottidis.

    B The musculus cricoarytenoideus changes the angle between the cartilagines thyroidea and cricoidea to increase tension on the plicae vocales but does not necessarily change their position in the larynx.
    C The musculus cricoarytenoideus lateralis rotates the cartilago arytenoidea inward, which adducts the plicae vocales and closes the rima glottidis.
    D The musculus arytenoideus transversus moves the two cartilagines arytenoideae toward each other, adducts the plicae vocales, and closes the rima glottidis.
    E The musculus thyroarytenoideus and its inferior fibers (musculus musculus vocalis) rotate the cartilago arytenoidea anteriorly, which relaxes (the vocalis tightens) the plicae vocales and closes (or has no effect on) the rima glottidis.

93. **C** The lobus pyramidalis of the glandula thyroidea is the embryological remnant of the ductus thyroglossus indicating the origin of the glandula thyroidea at the root of the tongue. It typically runs anterior to the prominentia laryngea of the cartilago thyroideus.

    A The lateral lobes of the glandula thyroidea reside lateral to the cartilago cricoidea and inferolateral to the cartilago thyroidea. They do not approach the midline (except at the isthmus) of the neck.
    B The isthmus glandulae thyroideae joins the left and right lateral lobes, anterior to the anterior arcus cartilaginis cricoideae. It is a midline structure, but it is not as superiorly located as the prominentia laryngea.
    D The glandula parathyroidea superior, a separate embryological structure (4th pharyngeal pouch) from the glandula thyroidea (thyroid diverticulum), resides deep to the lateral lobe of the glandula thyroidea. It maintains this lateral position and does not shift toward the midline.
    E The glandula parathyroidea inferior, a separate embryological structure (3rd pharyngeal pouch) from the glandula thyroidea (thyroid diverticulum), resides medial to the lateral lobe of the glandula thyroidea. It maintains this lateral position and does not shift toward the midline.

Chapter 15 Rest of Body Anatomy

94. **A** The musculus infraspinatus is innervated by the nervus suprascapularis (C4–C6) after it passes through the incisura scapulae, covered by the ligamentum transversum scapulae superius.

    B The musculus subclavius is innervated by the nerve to the subclavius (C5–C6), which passes inferior to the medial end of the clavicula. The nerve to the subclavius does not approach the scapula.
    C The musculus teres major is innervated by the nervus subscapularis inferior (C5–C6), which passes anterior to the musculus subscapularis in the axilla. The lower nervus suprascapularis reaches only the posterior lateral edge of the scapula, not in a superior position.
    D The musculus rhomboideus minor is innervated by the nervus dorsalis scapulae (C4–C5), which passes posterior and medial to the margo medialis of the scapula. The nervus dorsalis scapulae never reaches the superior lateral edge of the scapula, where the incisura scapulae is located.
    E Themusculus deltoideus is innervated by the nervus axillaris (C5–C6), which passes through the quadrangular space to reach the posterior undersurface of the musculus deltoideus. The nervus axillaris passes anterior to the superior edge of the musculus subscapularis, then passes posterior along the margo lateralis of the scapula.

95. **B** The venae brachiales (and cephalicae) drain into the lateral (and medial) end of the vena axillaris. From here, blood flows sequentially into the vena subclavia, vena subclavia, and vena cava superior before reaching the heart.

    A The vena cephalica is not directly connected to the vena brachialis. There are connections through the vena mediana cubiti, but valves prevent back (peripheral) flow from the vena brachialis to the vena cephalica.
    C The vena brachiocephalica is not directly connected to the vena brachialis. Between the two are both the vena axillaris and the vena subclavia. The vena brachiocephalica is necessary to drain brachial vein blood back to the heart.
    D The vena jugularis interna is not directly connected to the vena brachialis. Blood from the vena brachialis eventually drains through the vena subclavia, which joins with the vena jugularis interna, but there are valves in both the vena subclavia and the vena jugularis interna that prevent back (peripheral) flow between them.
    E The vena subclavia drains blood from the vena axillaris and some smaller veins, but it has no other major contributors from the arm. It runs inferior to the clavicula, whereas the vena brachialis ends at the distal extent of the axilla.

96. **E** The tuberositas radii is the insertion/distal attachment of the tendo of the musculus biceps brachii, which provides both forearm flexion and supination at the articulatio radioulnaris.

    A The sulcus intertubercularis is the insertion of the musculus pectoralis major.
    B The processus coracoideus scapulae is the insertion of the musculus pectoralis minor and the origin/proximal attachment for the musculi coracobrachialis and biceps brachii, caput breve.
    C The tuberositas ulnae is the insertion/distal attachment for the musculus brachialis, another flexor of the forearm.
    D The fossa olecrani humeri is the space in which the olecranon of the ulna fits during forearm extension. No muscles attach in this space.

97. **C** The left 8th vena intercostalis posterior drains into the vena hemiazygos. Communications from this vein drain to the right to reach the vena azygos and subsequently the vena cava superior prior to returning blood to the heart.

    A The vena cava inferior is not directly connected to the venae intercostales posteriores. To reach the vena cava inferior, blood would have to drain from the venae intercostales posteriores to the venae azygos (right) or hemiazygos (left) and then drain inferiorly to reach the venae lumbales ascendentes. From here, blood could drain through the venae lumbales to reach the vena cava inferior.
    B The vena cava superior is not directly connected to the venae intercostales posteriores. To reach the vena cava superior, blood would have to drain from the venae intercostales posteriores to the venae hemiazygos (left) or azygos (right). The vena hemizygos drains to the vena azygos, which in turn drains to the vena cava superior.
    D The vena azygos drains the venae intercostales posteriores on the right, not the left, side of the thorax. It collects blood from the venae hemiazygos and hemiazygos accessoria and drains into the vena cava superior, but there are typically no direct connections between the left venae intercostales posteriores and the vena azygos.
    E The ductus thoracicus is a lymphatic passage that drains lymph from the lower extremities, pelvis, and abdomen. No veins drain directly into this lymphatic structure.

98. **D** The ramus circumflexus is one of two major branches of the arteria coronaria sinistra. It wraps around the heart from anterior to posterior in the left atrioventricular sulcus, giving rise to one or more obtuse rami marginales sinistri that supply blood to the left side of the ventriculus sinister. It is paralleled by the vena cardiaca magna.

    A The ramus interventricularis anterior is a branch of the arteria coronaria sinistra that descends between the ventriculi dexter and sinister on the anterior heart. Its branches are the ramus lateralis and rami interventriculares septales that supply blood to the anterior left ventricle and septum interventriculare. The ramus interventricularis anterior is paralleled by the vena cardiaca magna before it turns into the left atrioventricular sulcus and starts to parallel the ramus circumflexus.
    B The ramus interventricularis posterior is a branch of the arteria coronaria dextra. These vessels run between the ventriculi dexter and sinister on the posterior aspect of the heart. Occasionally, the ramus interventricularis posterior arises from the ramus circumflexus of the arteria coronaria sinistra (left dominant heart).
    C The arteria coronaria dextra follows the right atrioventricular sulcus from the anterior aspect of the heart to the sulcus interventricularis posterior. The arteria coronaria dextra has the rami marginales dextri, but it does not supply blood to the left side of the heart. The vena cardiaca parva typically parallels the arteria coronaria dextra but still would not reach the left side of the heart before it drained into the sinus coronarius.
    E Thebesian vessels are veins that drain blood from the ventriculus dexter directly into the atrium dextrum, bypassing the vena cardiaca parva and the sinus coronarius. Because these vessels are restricted to the right side of the heart, there is no way for these small vessels to reach the left (obtuse) margin of the heart.

99. **A** A pulmonary embolism in the segmentum apicoposterius of the lobus superior pulmonis sinistri would result in breathlessness and chest wall pain along the posterior superior lateral margin of the left thorax.

    B A pulmonary embolism in the segmentum apicale of the lobus superior pulmonis sinistri would result in breathlessness and chest wall pain along the superior margin of the right thorax.
    C A pulmonary embolism in the segmentum laterale of the lobus medius pulmonis dextri would result in breathlessness and chest wall pain along the lateral margin of the right thorax.
    D A pulmonary embolism in the segmentum lingulare of the lobus superior pulmonis sinistri would result in breathlessness and chest wall pain along the midlateral margin of the left thorax.
    E A pulmonary embolism in the segmentum superius of the lobus inferior pulmonis sinistri would result in breathlessness and chest wall pain along the posterior and lateral margin of the left thorax.

Appendix A Anatomy of Local Anesthesia for Dentistry

100. **C** The needle passes through the musculus buccinator during a nervus alveolaris inferior block. The fact that the needle passes through muscle accounts for the particularly painful nature of this injection.

    A The needle passes into the pterygomandibular space lateral to the musculus pterygoideus medialis during an inferior alveolar injection. If the needle is mistakenly aimed too far medially, the injection will be given into the musculus pterygoideus, causing failure of anesthesia and trismus (muscle spasm) of this muscle.
    B A nervus alveolaris inferior block is given anteriorly to the musculus pterygoideus lateralis, so this muscle is not affected by this injection (intentionally or otherwise).
    D A nervus alveolaris inferior is given just laterally to the raphe pterygomandibularis, a landmark structure for this injection.
    E If a nervus alveolaris inferior block is aimed too posterolaterally, and bone is not contacted before the injection is given, then the needle is likely to have pierced the fascia parotidea. This will cause anesthesia of the branches of the nervus facialis that run through the glandula parotidea, leading to a temporary facial paralysis (Bell palsy).

Clinical Questions

For Questions **1 to 3**:

Mark has been experiencing a troubling series of symptoms involving his right upper limb. These symptoms have become exacerbated over the past few months. They include intermittent periods of intense pain in various areas of the limb and a tingling sensation (paresthesia) in others. He is also now experiencing various motor difficulties. He is sent for tests that include magnetic resonance imaging (MRI). It is discovered that he has a slipped discus intervertebralis that is impinging on nervus spinalis C5.

1. To which of the following areas of the upper limb would his pain and/or paresthesia be primarily localized?
    A. Superolateral aspect of the arm extending inferior to the lateral aspect of the midpoint of the forearm
    B. Axillary fold extending into the medial aspect of the arm
    C. Medial aspect of the arm and forearm
    D. Medial aspect of the forearm extending into the eminentia hypothenaris of the hand
    E. Lateral aspect of the forearm extending into the eminentia thenaris of the hand
2. Which of the following nerves would be totally dysfunctional as a result of a compression of C5?
    A. Nervus axillaris
    B. Nervus thoracodorsalis
    C. Nervus thoracicus longus
    D. Nervus dorsalis scapulae
    E. Nervus pectoralis lateralis
3. Which of the following actions would be least affected as a result of compression of C5?
    A. Abduction and adduction of the fingers
    B. Flexion at the elbow
    C. Abduction at the articulatio glenohumeralis
    D. Lateral rotation at the articulatio glenohumeralis
    E. Extension at the articulatio glenohumeralis

For Questions **4 to 7**:

Your friend William is walking down the street when he stares upward, then crumples to the ground. He lies there unconscious as you call for an ambulance. His wife arrives at the hospital, and after he becomes conscious, it is clear from his symptoms that he had an occlusion of the left arteria cerebri media.

4. One of the most obvious and prominent symptoms exhibited by William is almost total paralysis of his upper and lower limbs on the right side of his body. This occurred because of lack of blood flow to which of the following parts of the brain?
    A. Left capsula interna
    B. Left putamen
    C. Right gyrus precentralis
    D. Right premotor cortex
    E. Left gyrus postcentralis
5. Assuming that William is left brain dominant, in addition to the difficulty mentioned previously, all of the following symptoms are consistent with an occlusion of the arteria cerebri media, except for
    A. Apraxia (inability to perform a movement correctly in response to a verbal or written request)
    B. Alexia (inability to read)
    C. Agraphia (inability to write)
    D. Right-sided paralysis
    E. Anosognosia (inability to recognize disease or debilitation in oneself)
6. It is clear from William's interactions with those around him that he understands what is being said about him and what is being asked of him. However, when he is asked to respond to a question or speak in general, he can only respond with grunts and garbled utterances. It is clear that this is very frustrating to him. Based on this specific symptom, which of the following areas of his cerebrum is damaged?
    A. Posterior aspect of the gyrus temporalis superior
    B. Gyrus supramarginalis
    C. Gyrus lingualis
    D. Inferior frontal cortex
    E. Inferior aspect of the gyrus precentralis
7. If, for the sake of argument, the right arteria cerebri media was occluded rather than the left arteria cerebri media in a left brain–dominant individual, which of the following symptoms would be apparent?
    A. Inability to move his right hand
    B. Inability to move the musculi faciei on the right side of his face
    C. Inability to appreciate tonality in speech or in music
    D. Inability to calculate figures on a check during dinner
    E. Inability to understand what is spoken to him and responding with clearly enunciated but nonsense sentences

For Questions **8 to 11**:

Max is a 65-year-old patient of long standing, but you have not seen him for over a year. His primary complaint is that things "don't feel right" when he chews, specifically, on the left side of his mouth. He has the sensation that he just cannot seem to put his teeth into the correct position. The initial examination reveals a carious lesion of the dens molaris maxillaris secundus on the left side. Also, wear patterns and abfraction (pathological loss of tooth structure attributed to biomechanical forces or chemical degradation) on the left dentes maxillares are noted.

8. The initial thought was that Max was favoring his left side due to the pain associated with the carious tooth. To painlessly remove the decay, which of the following nerves need to be anesthetized?
    A. Rami alveolares superiores posteriores
    B. Nervus buccalis
    C. Ramus alveolaris superior medius
    D. Nervus palatinus major
    E. Nervus palatinus minor
9. Two weeks after the decay was removed, Max returns to the office with the same complaint. Now not only do things not "feel right," but he is also in pain. The pain at times radiates throughout his entire arcus dentalis maxillaris. Before you can explore the region, Max states that he wants all of the teeth anesthetized. You explain that this is not necessary and that the procedure for anesthetizing the entire nervus maxillaris is complex and potentially problematic. The most conventional form of this procedure would involve which of the following?
    A. Inserting a needle extraorally into the fossa infratemporalis and the foramen ovale. Fluid would then enter into the most inferior aspect of the cranium at the point of exit of the nervus maxillaris.
    B. Inserting a needle intraorally through the msuculus buccinator into the fossa infratemporalis, then placement of the needle adjacent to the foramen rotundum. Fluid would gain access to the inferior aspect of the cranium at the point of exit of the nervus maxillaris.
    C. Inserting a needle extraorally into the fossa infratemporalis and approximating the fissura pterygomaxillaris. Fluid would then gain access to the fossa pterygopalatina, and the nervus maxillaris would be anesthetized.
    D. Inserting a needle intraorally into the foramen palatinum majus. Fluid would then travel up the canalis palatinus major into the fossa pterygopalatina, and the nervus maxillaris would be anesthetized.
    E. Inserting a needle into the foramen infraorbitale. Fluid would

then be placed into the foramen and would travel posteriorly to the fossa pterygopalatina, and the nervus maxillaris would be anesthetized.

10. Max returns 3 weeks later. He is clearly agitated and states that things still do not "feel right." You carefully palpate the external aspect of his jaw and infratemporal region and discover the muscles that elevate the mandibula on the left side of his head seem to be slightly hypertrophied and spasmodic as compared with the same muscles on the opposite side. The muscles that you were able to palpate include the
    A. Musculus temporalis only
    B. Musculi temporalis and masseter
    C. Musculi temporalis, masseter, and buccinator
    D. Musculi temporalis, masseter, and zygomaticus major
    E. Musculi temporalis, masseter, and pterygoideus lateralis

11. As a result of the previous examination, you suggest that Max use a bite splint at night. He does as requested, but 1 month later, rather enraged, he returns with the same complaint i.e., that things do not "feel right" when he chews. You now ask him if there was any major health event or emergency that occurred during the year before the first examination. He states that he had a minor stroke from which he believes he has fully recovered. You contact the neurologist and discover that it was a truncus encephali stroke involving the pons. After a consultation with the neurologist, you tell Max that, unfortunately, there is very little that you can do to ameliorate his discomfort. Your rationale for this statement is the following.
    A. The motor nucleus of nervus cranialis (CN) V was damaged on the right side of the truncus encephali. This would explain the abnormal activity of the musculi masticatorii on the right side of the jaw.
    B. The nucleus mesencephalicus of CN V was damaged on the left side of the truncus encephali. This would explain the report of "things not feeling right," as this nucleus is responsible for proprioception impulses that travel to nerves of the dentes molares mandibulares and maxillares and sensory fibers associated with the articulatio temporomandibularis (TMJ).
    C. The principal sensory nucleus of CN V was damaged on the left side of the truncus encephali. This would explain the intense pain experienced.
    D. The pars caudalis nuclei spinalis nervi trigemini was damaged on the right side of the truncus encephali. This would explain the uneven wear patterns seen, as this nucleus helps to control the coordination of muscles of the TMJ on the left and right sides of the jaw.
    E. The nucleus interpolaris was damaged on the right side of the truncus encephali. This would explain the uneven wear patterns, as this nucleus is specifically responsible for fine touch and would come into play when Max tries to approximate his dentes maxillares to his dentes mandibulares.

For Questions **12 and 13**:

Your friend is lying in a hospital bed after being in a head-on automobile collision. Unfortunately, his classic car had neither seatbelts nor an airbag, so upon colliding with the other car, he catapulted forward, with his head violently hitting the windshield. Upon awaking, it was discovered that he was suffering with both anosmia (loss of olfaction) and bilateral total anopsia (total blindness in both eyes).

12. His anosmia possibly resulted from damage to fibers that run through the
    A. Fissura orbitalis inferior
    B. Foramen rotundum
    C. Foramen ovale
    D. Lamina cribrosa
    E. Foramen spinosum

13. The bilateral anopsia possibly resulted from damage to the optic chiasm because it was severed by which of the following broken shards of bone?
    A. Os ethmoidale
    B. Os frontale
    C. Ala minor ossis sphenoidalis
    D. Pars petrosa ossis temporalis
    E. Clivus

For Questions **14 to 16**:

A restoration needs to be performed on a carious lesion on a dens molaris secundus maxillaris. An anesthetic procedure takes place to numb the tooth. Unfortunately, sufficient care is not taken to ensure that the needle is sterile. In addition, when the needle is placed into the tissue, it is not withdrawn to discern whether or not it was inadvertently placed into a blood vessel.

Three days after the procedure, the patient is rushed to an emergency room with a fever of 104°F (40°C). The patient is dizzy, disoriented, and nauseated. He is also experiencing acute exophthalmia (marked protrusion of the bulbus oculi) of his left eye and difficulty moving his left eye laterally.

14. The anesthetic procedure was to anesthetize which of the following nerves?
    A. Ramus alveolaris superior medius
    B. Ramus alveolaris superior anterior
    C. Ramus alveolaris posterior superior
    D. Nervus palatinus major
    E. Nervus palatinus minor

15. The symptoms he is experiencing are a result of bacteria being introduced into the _____, which then traveled into the _____.
    A. Arteria carotis externa, arteria meningea media
    B. Vena ophthalmica, sinus cavernosus
    C. Vena maxillaris, vena retromandibularis
    D. Plexus pterygoideus, sinus cavernosus
    E. Infraorbital vein, sinus cavernosus

16. The difficulty the patient has in moving his eye laterally is directly related to irritation of the _____, resulting in dysfunction of the _____.
    A. Nervus abducens, musculus obliquus inferior
    B. Nervus oculomotorius, musculus rectus superior
    C. Nervus oculomotorius, musculus rectus inferior
    D. Nervus abducens, musculus rectus lateralis
    E. Nervus trochlearis, musculus obliquus superior

For Questions **17 to 20**:

Your patient has arrived with a carious lesion of his right dens molaris mandibularis secundus. You attempt a nervus alveolaris inferior anesthetic procedure. Initially, all appears to be proceeding as planned. However, ~5 minutes after the injection, the patient reports no lower lip anesthesia and a symptom that is quite worrisome. Based on this symptom, you realize that you have injected anesthetic fluid into the fascia parotidea.

17. What is the symptom that is causing you concern?
    A. Difficulty depressing the mandibula on the side of the injection
    B. Inability to close the rima palpebrarum on the side of the injection
    C. Inability to open the rima palpebrarum on the side opposite the injection
    D. Difficulty with swallowing
    E. Inability to raise the mandibula on the side opposite the injection

18. Which of these structures is found in the parotid space?
    A. Vena retromandibularis
    B. Arteria carotis interna
    C. Vena jugularis interna
    D. Arteria masseterica branch of the arteria maxillaris
    E. Arteria buccalis branch of the arteria maxillaris

19. These symptoms probably occurred as a result of the needle placement

that is

A. Too far superior and anterior
B. Too far posterior and inferior
C. Too far anterior and inferior
D. Too far medial and inferior
E. Too far medial and superior

20. A second injection was then performed to anesthetize the mandibular tooth. This did not provide the necessary anesthesia, and again it was assumed that the anesthetic fluid did not properly approximate the nervus alveolaris inferior. However, the lack of anesthesia might not have been due to the procedure but because there are accessory sensory fibers that sometimes supply the roots of the mandibular molars. These fibers travel on or with the

A. Nervus lingualis
B. Nervus buccalis
C. Nervus mylohyoideus
D. Ramus marginalis mandibularis
E. Ramus buccalis of CN VII

For Questions **21 to 24**:

A 35-year old man presents to the physician's office with a report of shooting, excruciating pain on the left side of his face. This is episodic pain that is described as being jabbed by an electrified pin every 10 seconds or so. The pain radiates down the external aspect of the mandibula and includes the skin over the mandibula, the general area of the lower extent of the fossa infratemporalis, and the mucosa of the tongue and internal aspect of the mouth. The pain is only on the left side. In addition, when asked to open his mouth, the patient cannot fully do so without experiencing the same excruciating pain. Furthermore, as he opens his mouth, the muscles that oppose this motion become spasmodic.

21. Based on the symptoms, it is determined that he is suffering from

A. Bell palsy
B. Trigeminal neuralgia
C. Geniculate neuralgia
D. Glossopharyngeal neuralgia
E. Temporal arteritis

22. A compression of which of the following nerves might be responsible for the aforementioned syndrome and the symptoms described in the scenario?

A. Nervus trigeminus
B. Nervus mandibularis
C. Nervus maxillaris
D. Nervus alveolaris inferior
E. Nervus lingualis

23. As stated, when asked to open his mouth, the patient experiences great difficulty as the muscles that oppose this action go into spasm. The muscles that are becoming spasmodic include the

A. Musculus buccinator
B. Musculus pterygoideus lateralis
C. Musculus temporalis
D. Musculus mylohyoideus
E. Venter anterior musculi digastrici

24. In a person facing this degree of pain, it is sometimes necessary to take rather extreme measures. One of these measures is to ablate the ganglion involved with the transmission of pain impulses back to the central nervous system. This procedure is known as percutaneous needle rhizotomy. In this case, to alleviate the pain, the ganglion that would need to be ablated is the

A. Ganglion geniculi
B. Ganglion trigeminale
C. Ganglion superius of CN IX
D. Ganglion pterygopalatinum
E. Ganglion superius of CN X

For Questions **25 to 28**:

A 25-year old male patient sits in your dental chair with an obvious disparity in the appearance of the right and left sides of his face. The entire left side of his face is drooping. This includes his lips and the muscles above and below his cavitas oris. He is also wearing an eye patch over his left eye. He tells you that the symptoms appeared "out of nowhere." He went to bed one night feeling normal and awoke the next morning with the symptoms you are observing. He states that there was no other precipitating factor that would account for what occurred. He also states that there is apparently nothing else that ails him, and he is not experiencing muscle paralysis in any other area of his face or body. It is now 1 month to the day since the symptoms first manifested themselves.

25. Based on his appearance and the onset of his problems, even before you discuss the matter with him, you conclude that he is suffering from

A. A left-sided cerebral stroke
B. A right-sided cerebral stroke
C. Trigeminal neuralgia
D. Bell's palsy
E. Glossopharyngeal neuralgia

26. On the other hand, it might be a compression of the nervus facialis that is unrelated to any of the syndromes or diseases related above. Based on these symptoms, and these symptoms only, it could be a compression of the nervus facialis

A. As it travels through the glandula parotidea
B. Just distal to the point at which it exits through the foramen stylomastoideum
C. Just proximal to the point at which it exits through the foramen stylomastoideum
D. Just proximal to the point at which the chorda tympani branches
E. Just distal to the point at which the chorda tympani branches

27. Before you relate your thoughts to your patient, he tells you that he is also suffering from diminished taste. He further informs you that he is wearing the eye patch so that the fluid (artificial tears) he is placing onto his cornea will not escape. This is necessary because he is not lacrimating in his left eye. Finally, he tells you he is experiencing anesthesia of a portion of the skin on the meatus acusticus externa. Based on this additional information, your analysis of where the compression of the nervus facialis has occurred has now changed. You now believe that the compression of the nervus facialis has occurred

A. As it travels through the glandula parotidea
B. Just proximal to the point at which the chorda tympani branches
C. Just proximal to the point at which the nervus petrosus major branches
D. Just distal to the point at which the nervus petrosus major branches
E. Just distal to the point at which the chorda tympani branches

28. You ask your patient to briefly remove his eye patch and notice that the upper eyelid is abnormally elevated. This is because the _____ that is innervated by the _____ is unopposed in its action.

A. Musculus orbicularis oculi, rami zygomatici of CN VII
B. Musculus orbicularis oculi, rami temporales of CN VII
C. Musculus levator palpebrae superioris, rami temporales of CN VII
D. Musculus levator palpebrae superioris, nervus oculomotorius
E. Musculi corrugator supercilii and frontalis working as a unit, rami temporales of CN VII

For Question **29**:

A patient presents himself to his physician with a persistent left-sided throat "tickle" and a nonproductive cough. He also says that as of late he has experienced an intermittent hoarse voice. The initial treatment is palliative with a course of throat lozenges, inhalants, and basic antiinflammatory drugs that are purchased over the counter. However, the patient returns in 2 weeks with the same complaint, and an X-ray of the thorax is ordered. Even though the X-ray results are speculative at best, because of the persistence of the symptoms, a computed tomography (CT) scan with contrast is ordered. As a result of the CT scan, an aneurysm of the arcus aortae is clearly visible.

29. Based on this, it is clear that the symptoms are a result of a compression of the
    A. Left nervus vagus
    B. Left ramus externus nervi laryngei superioris
    C. Left nervus laryngeus recurrens
    D. Left nervus laryngeus superior
    E. Left ramus internus nervi laryngei superioris

For Questions **30 to 32**:

A 35-year-old man presents with what he believes to be pain associated with "a left upper tooth." The pain seems to be rather diffuse, so he cannot be more specific. After a full set of dental X-rays and a thorough intraoral examination, no lesion is found to be associated with any of his maxillary or mandibular teeth. Furthermore, the gingiva appears to be essentially normal. Upon further questioning of the patient, he tells you the pain tends to recur and is worst during the spring and the fall.

30. Based on the patient's clinical presentation, even before you proceed with a full set of X-rays and other clinical tests, you suspect that his pain is associated with which of the following?
    A. Trigeminal neuralgia
    B. Masseteric spasms
    C. Maxillary sinusitis
    D. Auris media infection
    E. Temporomandibular dysfunction

31. One of the difficulties in determining the exact location of pain emanating in the head is that there are many structures found in a confined area. All of these structures send neuronal impulses to the structure in the brain responsible for determining which impulses are originating from which area. This structure is the
    A. Colliculus superior
    B. Colliculus inferior
    C. Thalamus
    D. Hypothalamus
    E. Globus pallidus

32. Although the structure in question 31 is responsible for locating pain, the actual perception of pain is associated with a different area of the brain. This area is the
    A. Gyrus postcentralis
    B. Gyrus precentralis
    C. Gyrus temporalis superior
    D. Gyrus lingualis
    E. Gyrus cinguli

For Questions **33 to 35**:

A 58-year-old man presents to the clinic complaining of pain that prevents him from fully opening his mouth. He has a lump over the angulus mandibulae on the left side of his jaw that he says has been slowly getting bigger over the past 18 months but that it has not hurt until recently, so he was not worried about it. Because the patient has a limited opening, you decide that a panoramic radiograph is in order. Based on further testing and a biopsy, it is discovered that the lump is an ameloblastoma that originated within the mandibula.

33. The insertions (distal attachments) of what two musculi masticatorii may be displaced as this tumor continues to disrupt the angle of the mandibula?
    A. Musculi pterygoidei medialis and lateralis
    B. Musculi musculi pterygoideus medialis and masseter
    C. Masseter and temporalis
    D. Musculi temporalis and pterygoideus medialis
    E. Musculi temporalis and pterygoideus lateralis

34. From which branchial arch do the musculi masticatorii develop?
    A. Arcus pharyngeus primus
    B. Arcus pharyngeus secundus
    C. Arcus pharyngeus tertius
    D. Arcus pharyngeus quartus
    E. Arcus pharyngeus quintus

35. Which of the following nerves is most likely to be initially displaced by this tumor?
    A. Nervus buccalis
    B. Nervus lingualis
    C. Nervi temporales profundi
    D. Nervus pterygoideus lateralis
    E. Nervus alveolaris inferior

For Questions **36 to 39**:

A 73-year-old man complains that things are "tasting funny" and that this difficulty with taste has existed for the past few months. He says that he does not have a fever and has not suffered with a cold or virus in the past 3 months. He does not smoke cigarettes, a pipe, or cigars, nor does he chew tobacco.

36. You initially examine his tongue to discern whether there is any damage that might affect the caliculi gustatorii on his tongue. You do this based on the knowledge that taste to the anterior two-thirds of the tongue initially runs in the
    A. Nervus glossopharyngeus
    B. Nervus alveolaris inferior branch of the nervus trigeminus
    C. Chorda tympani branch of the nervus facialis
    D. Nervus petrosus major branch of the nervus facialis
    E. Nervus petrosus minor branch of the nervus glossopharyngeus

37. Caliculi gustatorii are primarily associated with which of the following papillae of the tongue?
    A. Filiformes
    B. Fungiformes
    C. Vallatae
    D. Foliatae
    E. Caliculi gustatorii are found in abundance on all of the aforementioned papillae.

38. Another problem that can affect taste, especially in older individuals, is a decline in salivary fluid production. Parasympathetic fibers that stimulate salivary output run with which of the following nerves?
    A. Nervus petrosus major
    B. Nervus petrosus minor
    C. Nervus petrosus profundus
    D. A and B only
    E. A, B, and C

39. Ganglia involved with fibers that stimulate salivary output from the glandulae salivariae majores include which of the following?
    A. Ganglion ciliare
    B. Ganglion cervicale superius
    C. Ganglion cervicale medium
    D. Ganglion submandibulare
    E. Ganglion pterygopalatinum

For Questions **40 to 42**:

A man is rushed into the emergency room displaying exaggerated swelling in the submandibular area. The patient is clearly having difficulty breathing, has a fever of 103°F (39.4°C), tachycardia, and tachypnea. He has a hard swelling in the floor of the mouth resulting in superoposterior displacement of the tongue, which is interfering with the airway. The patient is presumed to be suffering with Ludwig's angina. As treatment begins, the medical staff works to maintain the airway, administers antibiotics, and makes an external incision in the submandibular area to begin drainage.

40. The infection is found in which of the following spaces?
    A. Submandibular only
    B. Sublingual only
    C. Submandibular and sublingual
    D. Submandibular and submental
    E. Submandibular, sublingual, and submental

41. The infection can originate from which of the following teeth?
    A. Dentes molares mandibulares only
    B. Dentes incisivi, canini, and premolares mandibulares only
    C. Any dens mandibularis
    D. Dentes molares maxillares
    E. Any dens maxillaris

42. If it is necessary to insert an intraoral drain, the mucosa of the floor of the mouth will need to be incised. Which of the following structures will be the first to be encountered?
    A. Ductus submandibularis
    B. Nervus lingualis
    C. Arteria lingualis
    D. Nervus hypoglossus
    E. Nervus glossopharyngeus

For Questions **43 to 45**:

A 50-year-old woman arrives in your office with a painless mass in the floor of her mouth. She reports that the mass first appeared 2 years ago, but it remained small and painless, so she never bothered seeing a clinician. Recently, the mass has begun to grow at a faster pace. The patient also reports a history of tobacco and alcohol use, including smoking four packs of cigarettes a week since her early 20s. Upon examination you find a nonulcerated, red-purple mass in the floor of her mouth just lingual to the patient's right dentes posteriores mandibulares. External palpation of the trigonum submandibularis reveals an enlarged, slightly tender glandula submandibularis that feels fixated to the surrounding tissue. A CT scan confirms an enlarged glandula submandibularis. You decide to perform an excisional biopsy.

43. When performing the extraoral excisional biopsy, one must be careful when resecting the glandula submandibularis not to damage which of the following structures that runs through the gland?
    A. Vena facialis
    B. Arteria facialis
    C. Arteria lingualis
    D. Nervus hypoglossus
    E. Anterior division of the vena retromandibularis

44. Likewise, during resection one must be very careful not to damage which of the following structures that runs on the superficial surface of the gland?
    A. Ramus cervicalis of the nervus facialis
    B. Ramus marginalis mandibularis of the nervus facialis
    C. Nervus mentalis branch of the nervus trigeminus
    D. Inferior fibers of the nervus buccalis branch of the nervus trigeminus
    E. Inferior fibers of the rami buccales of the nervus facialis

45. Once the gland is exposed, it is clear that a portion of the glandula submandibularis around the
    A. Musculus hyoglossus
    B. Venter anterior musculi digastrici
    C. Venter posterior musculi digastrici
    D. Musculus genioglossus
    E. Musculus mylohyoideus

For Questions **46 to 48**:

A 55-year-old male patient called your office with a complaint that his right rear lower tooth really hurt. You suggested he come see you so that you could take a look at the tooth and the structures that surrounded it. Five days later, he called back happily proclaiming that he was no longer in pain. You suggested that he should see you anyway. Your concern was that if it was an infection in the tooth, it could have now progressed from the tooth into a fascial space. Three days after his second call to you, the patient appears in an emergency room with the following symptoms:

- Temperature of 101.3°F (38.5°C)
- Elevated white blood cell count
- Reddened and flushed appearance on both sides of the neck
- Pain upon movement of the neck
- Great difficulty swallowing and breathing

Dental examination and subsequent X-rays revealed that the apparent infection probably emanated in the dens molaris secundus mandibularis and spread to the spatium retropharyngeum and the danger space.

46. In this case, it is irrelevant whether the infection is in the spatium retropharyngeum and/or danger space because the fascia between the two has degenerated. This fascia is the
    A. Lamina prevertebralis fasciae cervicalis
    B. Lamina pretrachealis fasciae cervicalis
    C. Fascia buccopharyngealis
    D. Medial aspect of the vagina carotica
    E. Alar layer of the lamina prevertebralis fasciae cervicalis

47. One of the primary concerns of infections that gain access to the spatium retropharyngeum is that they can then spread to the
    A. Sinus maxillaris
    B. Sinus cavernosus
    C. Mediastinum
    D. Cavitas peritonealis
    E. Orbita

48. Because of the marked difficulty in breathing, it is decided that an emergency tracheostomy must be performed. Sometimes, in performing a tracheostomy, the glandula thyroidea must be cut vertically at its isthmus. Why is this not a problem with respect to the health of the patient?
    A. As humans age, the glandula thyroidea markedly regresses, and by the age of 55, it has little or no functional significance.
    B. The glandula thyroidea is an exocrine gland, and its ducts are located inferolaterally. Thus, a vertical incision through the midline of the gland will not affect its ability to send substances to the remainder of the body.
    C. The glandula thyroidea is an exocrine gland, and its ducts are located superolaterally. Thus, a vertical incision through the midline of the gland will not affect its ability to send substances to the remainder of the body.
    D. The glandula thyroidea is an endocrine gland that secretes copious amounts of angiogenic factors. Thus, even with damage to the midline venous and arterial structures, once it is placed back into position, additional arteries and veins grow to take their place.
    E. The glandula thyroidea is an endocrine gland, and its hormones are secreted into veins that are found on the lateral aspect of the gland. These veins are normally not harmed when a midline vertical incision is performed.

For Questions **49 to 51**:

Tim Brody, a quarterback for the champion Northwest Coffee Grinders, is viciously slammed to the ground in the semifinals. The training staff rushes onto the field, where he lies semiconscious. They immediately shine a light in his left eye, and as they do so, they check the response of the pupils in the left and right eyes. Based on what they see, they are relatively pleased, and as Tim begins to become alert, they raise him to his feet. He staggers to the sidelines, where the trainers sit him down for further assessment.

49. By shining the light in one eye, then looking at both eyes, the training staff is testing for which of the following reflexes?
    A. Corneal
    B. Pupillary dilator
    C. Vestibulo-ocular
    D. Consensual light
    E. Accommodation

50. All of the following structures are involved in the aforementioned reflex, except for the
    A. Corpus geniculatum mediale
    B. Ganglion ciliare
    C. Nuclei viscerales nervi oculomotorii
    D. Commissura posterior
    E. Nervus opticus

51. This test is performed, at least in part, to try to determine if which of the following occurred?
    A. Tear of the lining of the ventriculus lateralis
    B. Epidural hematoma
    C. Subdural hematoma
    D. Occlusion of the arteria cerebri anterior
    E. Occlusion of the arteria cerebri posterior

For Questions **52 to 54**:

A middle-aged female dental patient returned for a prosthodontic evaluation after undergoing a radical neck dissection, mandibular reconstruction, and bone grafting following removal of a tumor on the right side of her neck and face. The evaluation occurred 8 weeks after the operation, and the healing was for all intents and purposes complete. The patient experienced difficulty rotating her head. It was necessary for her to rotate her trunk to face the assistant. The patient also experienced difficulty elevating her shoulder on her right side. She reported sporadically experiencing muscle spasms and pain in the neck. Additionally, when asked to protrude her tongue, it was noted that the patient's tongue deviated to the right (see photograph).

52. The diminished ability to rotate her head is most likely due to
    A. Idiopathic spasmodic torticollis (abnormal wrenching of the neck)
    B. Damage to the nervus accessorius on the right side as a result of a surgical complication
    C. Damage to the nervus vagus on the right side as a result of a surgical complication
    D. Damage to the ansa cervicalis on the right side as a result of a surgical complication
    E. Damage to the nervus phrenicus on the right side as a result of a surgical complication

53. Based on the movement of the tongue seen in the patient, which of the following nerves was probably damaged while surgically removing the tumor in the mandibula?
    A. Nervus alveolaris inferior
    B. Chorda tympani
    C. Nervus hypoglossus
    D. Nervus mandibularisr
    E. Nervus glossopharyngeus

54. As stated previously, when asked to stick out her tongue, what occurred is what is shown in the photo below. Based on this, which of the following muscles is not functioning properly?
    A. Right hyoglossus
    B. Left hyoglossus
    C. Right genioglossus
    D. Left genioglossus
    E. Neither the left genioglossus nor the left hyoglossus is properly functioning.

For Questions **55 to 58**:

A.J., a 35-year-old female patient, tells you that she has been diagnosed with breast cancer and is considering a modified radical mastectomy. She has had extensive discussions with her primary physician and an oncologist. It is feared that the cancer is in the first stages of possibly spreading through her lymphatic system to the nodi lymphoidei axillares.

55. All of the following are considered to be part of the nodi lymphoidei axillares except for the
    A. Nodi pectorales
    B. Nodi laterales
    C. Nodi subscapulares
    D. Nodi infraclaviculares
    E. Nodi apicales

56. A modified radical mastectomy is being considered rather than a full radical mastectomy. In a modified radical mastectomy, the musculus pectoralis major is spared. This not only provides mass on the anterior chest wall, thus aiding with a possible breast reconstruction procedure, but also spares which of the following motions performed by the musculus pectoralis major?
    A. Inferior rotation of the scapula
    B. Superior rotation of the scapula
    C. Medial rotation of the humerus
    D. Abduction of the humerus
    E. Extension of the humerus

57. In a radical mastectomy, the lymph nodes and adipose tissue in the area of the chest and axilla are removed. Because of its placement on the superficial surface of the muscle that it innervates, as well as its proximity to the axilla, one of the following nerves is sometimes severed in the procedure. This nerve is the
    A. Nervus thoracicus longus
    B. Nervus pectoralis medialis
    C. Nervus pectoralis lateralis
    D. Nervus thoracodorsalis
    E. Nervus axillaris

58. When the nerve mentioned in question 56 is severed, the muscles that retract the scapulae are basically unopposed in their action, resulting in "winged scapulae." Muscles that retract the scapulae include the

    A. Musculus rhomboideus
    B. Musculus teres major
    C. Musculus teres minor
    D. Musculus latissimus dorsi
    E. Musculus longissimus

For Questions **59 to 62**:

A 55-year-old rock star is preparing for a concert at the Palladium in London when he experiences intense midsternal pain. He is rushed to the hospital and submitted to a series of blood tests and an electrocardiogram (ECG). Neither the blood tests nor the ECG indicate he has had a heart attack. He feels somewhat relieved with the news, but the chest pains, though not as pronounced, still remain. Because of the unrelenting pain, it is decided that he should undergo an angiography. The results of the angiography are also negative.

59. The arteries that were visualized using the angiography, as well as with the arteries from which they branch, are the

    A. Arteria coronaria sinistra that branches from the arcus aortae
    B. Ramus interventricularis anterior that branches from the arteria coronaria dextra
    C. SRamus nodi sinuatrialis that branches from the arteria coronaria dextra
    D. Ramus interventricularis posterior that branches from the arteria coronaria sinistra
    E. Ramus marginalis dexter that branches from the aramus interventricularis anterior

60. Pain from the heart can be referred to areas other than the midsternal region. These areas normally include all of the following except for the

    A. Left shoulder
    B. Posterior neck
    C. Midline of the mandibula
    D. Anterior aspect of the neck
    E. Right hypogastrium

61. The pain could be referred from areas or organs other than the heart. These organs include the

    A. Oesophagus
    B. Gaster
    C. Pancreas
    D. A and B only
    E. A, B, and C

62. After further testing, it is determined that the star is suffering with pericarditis, and an appropriate treatment is begun. One of the necessary steps is to drain excess pericardial fluid from the pericardial space. This space is found between which of the following two layers?

    A. Pericardium fibrosum and outer pericardial fat
    B. Pericardium fibrosum and the lamina parietalis of the pericardium serosum
    C. Lamina parietalis of the pericardium serosum and the lamina visceralis of the pericardium serosum
    D. Lamina serosa of the pericardium viscerale and the myocardium
    E. Myocardium and endocardium

For Questions **63 to 65**:

A 25-year-old woman is riding her bicycle on a busy street in Boston. As she rides past a row of cars, one of the drivers opens the door without looking. She does not have time to stop and catapults over the door. As she lands, she attempts to break her fall by throwing her right hand forward. The palm of her hand hits the ground, with the force of the fall being sent up through her wrist, forearm, and arm. Initially, her hand and wrist are sore, but over the next couple of hours, the soreness seems to subside. However, upon looking at her wrist, she sees a pronounced black-and-blue mark forming over the ventral aspect of her wrist and the extreme distal portion of her forearm. She goes to her primary physician, who expresses some alarm and informs her that her wrist may be broken and that she may be suffering from anterior compartment syndrome. Her physician makes an immediate appointment for her to see an orthopedist specializing in the upper limb. The orthopedist takes immediate action to drain the blood from the compartimentum antebrachii anterius and repair the fracture.

63. Which of the following nerves is found in the compartimentum antebrachii anterius and also passes through the canalis carpi with the tendines musculi flexoris digitorum profundi?

    A. Ramus profundus nervi radialis
    B. Ramus superficialis nervi radialis
    C. Nervus cutaneus antebrachii lateralis
    D. Nervus ulnaris
    E. Nervus medianus

64. If left unabated, the accumulation of blood could compress the nerve and cause permanent dysfunction of which of the following muscles?

    A. Musculus flexor pollicis longus
    B. Musculus flexor pollicis brevis
    C. Musculus flexor digitorum superficialis
    D. Musculus flexor carpi radialis
    E. All of the above

65. If this compression did occur, which of the following actions would be most affected?

    A. Fine motor movements of the thumb
    B. Adduction of the thumb
    C. Flexion of the fingers
    D. Extension at the articulationes carpometacarpales
    E. All of the above

Answer Explanations

1. **A** The dermatomal distribution for C5 is the superolateral aspect of the arm extending inferior to the lateral aspect of the midpoint of the forearm; therefore, pain and/or paresthesia would be localized to these areas.

   B The axillary fold extending into the medial aspect of the arm is the dermatomal distribution for T1 or T2.
   C The medial aspect of the arm and forearm is the dermatomal distribution that encompasses portions of T1 and C8.
   D The medial aspect of the forearm extending into the eminentia hypothenaris is the dermatomal distribution for C8.
   E The lateral aspect of the forearm extending into the eminentia thenaris of the hand is the dermatomal distribution for C6.

2. **D** The nervus dorsalis scapulae contains fibers from C5 only, so it would be totally dysfunctional.

   A The nervus axillaris contains fibers from both C5 and C6, so it would not be totally dysfunctional.
   B The nervus thoracodorsalis contains fibers from C6–C8, so it would be completely functional.
   C, E The nervi thoracicus longus and pectoralis lateralis contain fibers from C5–C7, so they would not be totally dysfunctional.

3. **A** Abduction and adduction of the fingers are accomplished through the actions of the musculi interossei, which are innervated by the nervus ulnaris. The nervus ulnaris is composed of fibers from C7 to T1, so it would be totally unaffected by compression of C5.

   B Flexion at the elbow is primarily, although not exclusively, accomplished through the action of the musculi brachialis and biceps brachii. These muscles are innervated by the nervus musculocutaneus, which contains neuronal fibers from C5 to C7. There would be a slight diminishment in this action. It should be remembered that the musculus brachioradialis also participates in flexion at the elbow. The musculus brachioradialis is innervated by the nervus radialis, which receives neuronal fibers from C5 to T1. The nervus radialis would probably be almost thoroughly functional, as would the nervus brachioradialis.
   C Abduction at the articulatio glenohumeralis is accomplished through the actions of the musculus supraspinatus and medial fibers of the musculus deltoideus. The musculus supraspinatus is innervated by the nervus suprascapularis, which receives neuronal fibers from C5 and C6. The musculus deltoideus is innervated by the nervus axillaris, which receives fibers from C5 and C6. Thus, these nerves, muscles, and actions would be affected as a result of compression of C5.
   D Lateral rotation at the glenohumeral joint is accomplished through the actions of the teres minor, infraspinatus, and posterior fibers of the deltoid muscle. The teres minor and deltoid are innervated by the nervus axillaris (described in answer explanation C). The infraspinatus is innervated by the nervus suprascapularis (described in answer explanation C).
   E Extension at the glenohumeral joint is accomplished through the actions of the posterior fibers of the musculi deltoideus, teres major, and latissimus dorsi. The musculus teres major is innervated by the lower nervus subscapularis, which receives fibers from C5 and C6. The posterior fibers of the musculus deltoideus are innervated by the nervus axillaris, which receives fibers from C5 and C6. The musculus latissimus dorsi is innervated by the nervus thoracodorsalis, which receives fibers from C6 through C8.

4. **A** Motor fibers that synapse on cornu anterius cells of the medulla spinalis originate in the contralateral motor and premotor cortices as part of the tractus pyramidalis, specifically, the fibrae corticospinales (lateral and anterior). Prior to decussating, these fibers travel in the capsula interna. Thus, damage to the left capsula interna, which is supplied via branches of the arteria cerebri media (specifically, the arteriae centrales anterolaterales), would result in contralateral paralysis. Therefore, in William, damage to the left capsula interna would result in paralysis of the right upper and lower limbs.

   B The putamen, left or right, is involved in modulation, not initiation, of motion. Damage to the putamen, such as in Huntington's disease, would result in a multiplicity of motor symptoms, including ballismus, but not paralysis.
   C, D Motor fibers that originate in the motor and premotor cortices travel to contralateral cornu anterius cells. Thus, damage to the right gyrus precentralis and/or right premotor cortices would result in paralysis of the left limbs, not the right.
   E The gyrus postcentralis is involved with interpretation of sensory input, not motor output.

5. **E** Anosognosia is associated with damage to the right hemispherium cerebri in a left brain–dominant individual.

   A–C Apraxia, alexia, and agraphia are associated with damage to the left hemispherium cerebri of a left brain–dominant individual.
   D Right-sided paralysis will occur because the left gyrus precentralis and premotor cortex are supplied by branches of the left middle arteria cerebri media. Also, the left arteria centralis anterolateralis is a branch of the left arteria cerebri media, and lack of blood flow to the arteriae centrales anteriores can result in damage to the left capsula interna, left putamen, left globus pallidus, and left nucleus caudatus. This will also result in paralysis of the right side of the body.

6. **D** The inferior frontal cortex contains Broca's area. It is in this area that motor impulses from the gyrus precentralis and premotor cortices, among other areas, cascade. These are then coordinated so the muscle groups needed to articulate speech can work as a unit. Damage to Broca's area results in William's symptoms.

   A Wernicke's area is found in the posterior aspect of the gyrus temporalis superior. Damage to this area results in an individual who is often fluent in language, but the conversation makes no sense in context.
   B Damage to the gyrus supramarginalis can result in anomia (a problem with word finding or recall) or alexia (inability to read), among other problems. However, it does not result in the symptoms associated with William.
   C The gyrus lingualis, located in the lobus occipitalis, is involved with sight, not speech.
   E The gyrus precentralis is involved with sensory perception and coordination of sensory information from various areas of the cerebrum. Damage to the gyrus precentralis produces numerous sensory deficits but not the symptom listed above.

7. **C** Prosody, or the ability to recognize tonality in speech or music, is associated with the right hemispherium cerebri of a left brain–dominant individual. Thus, this would be affected in an individual with an occlusion of the right arteria cerebri media.

   A Occlusion of the arteria cerebri media results in contralateral, not ipsilateral, paralysis of the trunk and limbs.
   B Occlusion of the arteria cerebri media results in contralateral paralysis of the musculi faciei inferior to the arcus zygomaticus, not total ipsilateral paralysis of the musculi faciei.
   D Acalculia, or the inability to perform mathematical calculations, is associated with the left hemispherium cerebri of a left brain–dominant individual. It would be unaffected in an occlusion of the right arteria cerebri media.
   E Inability to speak sentences that make sense in response to a verbal or written request is associated with damage to Wernicke's area, which is found in the left hemispherium cerebri of a left brain–dominant individual. This would not occur in an individual with an occlusion of the right arteria cerebri media.

8. **A** The ramus alveolaris superior posterior on each side innervates the dentes molares maxillares and their associated buccal gingiva, mucosa, and periosteum.

   B The nervus buccalis on each side innervates the mucosa of the cheek and the gingiva between the dentes premolaris mandibularis secundus and molares, as well as the trigonum retromolare. It does not innervate any teeth.
   C The ramus alveolaris superior medius on each side (when present) innervates the radices of the dentes premolares primus and secundus and the radix mesiobuccalis of the dens molaris primus.
   D The nervus palatinus major innervates the palatal gingiva, mucosa, and periosteum from the dens premolaris primus maxillaris to the posterior palatum durum to the midline of the palatum durum on the same side as the injection, that is, the posterior two-thirds of the palatum durum. The anterior two-thirds of the palatum durum is supplied by the nervus nasopalatinus.
   E The nervus palatinus minor` supplies the mucosa of the palatum molle.

9. **D** The foramen palatinum majus and canalis palatinus major are sufficiently large so that a small-bore needle can be placed within the foramen and fluid expressed that can gain access to the fossa pterygopalatina. The nervus maxillaris lies within the fossa.

   A, B Under no circumstances would anesthetic fluid, by any direction or means, be intentionally placed into the cranial vault. This could have disastrous effects on the brain.
   C Under extreme circumstances, fluid could be injected into the fossa pterygopalatina via the extraoral route. However, this is extremely dangerous, as the needle could damage any number of structures in the fossa infratemporalis, including the nervus mandibularis and its two major branches (nervi alveolaris inferior and lingualis), arteria maxillaris, and plexus pterygoideus of veins. Also, bacteria from the skin or superficial fascia could enter the fossa via this route.
   E In theory, anesthetic fluid could be placed into the foramen infraorbitale and expressed through the canalis infraorbitalis into the canalis pterygopalatinus. However, because of the force needed, there are several side effects that could occur, including temporary paralysis of the extraocular muscles and temporary blindness. These side effects are a result of anesthetic fluid traveling from the canalis infraorbitalis into the orbita.

10. **B** Both the musculi temporalis and masseter elevate the mandibula, and both can be externally palpated (therefore not answer choice A). The musculus temporalis participates in elevation, retrusion, and lateral excursion of the mandibula. The musculus masseter participates in elevation, protrusion, retrusion, and lateral excursion of the mandibula.

    C The musculus buccinator does not elevate the mandibula; rather, it presses the cheek against the dentes molares, working with the tongue to keep food between the occlusal surfaces and out of the vestibulum oris.
    D The musculus zygomaticus major does not elevate the mandibula but rather pulls the corner of the mouth superiorly and laterally.
    E The musculus pterygoideus lateralis functions in depressing, protruding, and medially excursing the mandibula (inferior head). It also functions in stabilizing the mandibula during retrusion (superior head). In addition, this muscle cannot be palpated externally.

11. **B** The nucleus mesencephalicus nervi trigemini is specifically associated with proprioception from the TMJ, the muscles that act upon it, and the teeth that directly surround it. Damage to the ipsilateral nucleus mesencephalicus of CN V would result in the symptoms described.

    A Damage to the motor nucleus of CN V, and or hyperactivity associated with the motor nucleus of V, could result in the hyperactivity associated with muscles, but the damage would need to be ipsilateral to the effect. Thus, it is the left motor nucleus of CN V that would need to be damaged, not the right.
    C The principal sensory nucleus of CN V is responsible for proprioception in the majority of the areas of the head and fine touch. However, the specific areas described in the question are served by the nucleus mesencephalicus of CN V.
    D The pars caudalis of the nucelus spinalis of CN V is involved with pain, temperature, pressure, and crude touch. It is not involved with coordinating muscle activity.
    E The function of the nucleus interpolaris is still a matter of conjecture, but it is definitely not involved with fine touch. Also, if it were to be involved, it would need to be located on the left side of the truncus encephali, not the right.

12. **D** Fibers of the nervus olfactorius travel through the lamina cribrosa of the os ethmoidale. The force of the collision as it was transmitted posteriorly could break through this rather tenuous bone.

    A The nervus and arteria infraorbitalis travel through the fissura orbitalis inferior.
    B The nervus maxillaris branch of the nervus trigeminus (CN V) travels through the foramen rotundum.
    C The nervus mandibularis branch of the nervus trigeminus and the nervus petrosus minor branch of the nervus glossopharygeus travel through the foramen ovale.
    E The arteria meningea media and ramus meningeus nervi mandibularis (nervus spinosus) travel through the foramen spinosum.

13. **C** The force of his head hitting the windshield during the collision was transmitted back through the os frontale to the suture between the os frontale and ala minor ossis sphenoidalis, causing breakage of the ala minor and a severing of the chiasma opticum.

    A As stated in Q12, fibers of the olfactory, not the optic, nerve travel through the lamina cribrosa of the os ethmoidalis.
    B The os frontalis is sufficiently massive, so that it probably would not break and cause the damage as described.
    D, E The pars petrosa ossis temporalis and the clivus lie posterior to all of the structures listed in the scenario.

14. **C** The rami alveolares superiores alveolares carry sensory fibers to the dentes molares maxillares, a portion of the mucosa of the sinus maxillaris, a portion of the buccal gingiva of the dentes molares maxillares, and a portion of the cheek. They are the nerves that are anesthetized in this procedure.

    A The ramus alveolaris superior medius carry sensory fibers to the dentes premolares and associated buccal gingiva and possibly the radix mediobuccalis of the dens molaris primus.
    B The rami alveolares superiores anteriores carries sensory fibers to the dentes incisivi mediales and laterales, canini, the mucosa of the sinus maxillaris, the labial gingiva associated with the dentes incisivi and dentes canini maxillares, and various nasal branches to the mucosa of a portion of the septum nasi, wall, and floor of the cavitas nasi.
    D The nervus palatinus major supplies the palatine gingiva and mucosa from the dentes premolares maxillares posteriorly.
    E The nervus palatinus minor supplies sensory innervation to the mucosa of the palatum molle.

15. Overall, the symptoms described are indicative of a sinus cavernosus thrombosis. The most common organism introduced into the sinus to cause the thrombosis is Staphylococcus aureus, with streptococci and pneumococci being less common (Andreoli et al., Cecil Essentials of Medicine, 6th ed. Elsevier, 2004). This question relates to the manner by which the organisms were introduced into the sinus.
    D Small tributaries of the plexus pterygoideus can be punctured in an attempt to anesthetize the rami alveolares superiores posteriores. The plexus pterygoideus communicates with the sinus cavernosus via a system of venae emissariae.

    A The arteria meningea media is a branch of the arteria carotis externa, but neither connects to the sinus cavernosus.
    B The vena ophthalmica does drain into the sinus cavernosus. However, in a procedure to anesthetize the dentes molares maxillares, the needle should not be in the vicinity of the vena ophthalmica.
    C The vena maxillaris does drain into the vena retromandibularis. However, the vena retromandibularis does not drain into the sinus cavernosus.
    E The vena infraorbitalis drains into the plexus pterygoideus. However, in a procedure to anesthetize the dentes molares maxillares, the needle should not be in the vicinity of the vena infraorbitalis.

16. **D** The nervi oculomotorius, trochlearis, and abducens nerves all travel through the sinus cavernosus. However, the nervi oculomotorius and trochlearis travel in its lateral aspect and are wrapped in, and protected by, the dura mater. In contrast, the nervus abducens runs through the center of the sinus and is unprotected. Thus, in a sinus cavernosus thrombosis, symptoms involving the nervus abducens are seen before those associated with either the nervus trochlearis or oculomotorius. The nervus rectus lateralis, innervated by the nervus abducens, moves the bulbus oculi laterally.

    A Themusculus obliquus inferior primarily acts in elevation of the bulbus oculi. It is innervated via fibers of the nervus oculomotorius not the abducens.
    B The musculus rectus superior is innervated via fibers of the oculomotor nerve, but its primary action is elevation of the bulbus oculi. It plays a minor role in adduction of the bulbus oculi.
    C The musculus rectus inferior is innervated via fibers of the nervus oculomotorius, but its primary action is depression of the bulbus oculi. It plays a minor role in adduction of the bulbus oculi.
    E The musculus obliquus superior primarily acts in depression of the bulbus oculi. It is innervated via branches of the nervus trochlearis. It plays a minor role in abduction of the bulbus oculi, but damage to it, in and of itself, would not cause major difficulty in moving the bulbus oculilaterally.

17. **B** Lowering the palpebra superior is achieved via the musculus orbicularis oculi, which is innervated by branches of the nervus facialis (CN VII). The nervus facialis runs through the parotid space and thus would be anesthetized on the side of the injection as a result of the procedure described.

    A Depressing the mandibula is accomplished through the action of the musclus pterygoideus lateralis, suprahyoideus, and infrahyoideus. The musculus pterygoideus lateralis, musculus mylohyoideus, and venter anterior musculi digastrici are innervated by branches of the nervus mandibularis division of the nervus trigeminus (CN V_3). The venter posterior musculi digastrici and musculus stylohyoideus are innervated by branches of the nervus facialis (CN VII). The musculi geniohyoideus and thyrohyoideus are innervated by fibers of C1, and the remainder of the musculi infrahyoidei are innervated by branches of the ansa cervicalis. None of these nerves run through the parotid space.
    C Raising the palpebra superior is achieved via the musculus levator palpebrae superioris, which is innervated by the nervus oculomotorius. This also would be unaffected, as it is on the opposite side of the injection.
    D Swallowing is achieved via branches of the nervi glossopharyngeus (CN IX), vagus (CN X), and aaccessorius (CN XI).
    E Raising the mandibula is accomplished via the musculi temporalis, masseter, and pterygoideus medialis, which are innervated by branches of the nervus mandibularis division of the nervus trigeminus (CN V_3). They would also be unaffected on the opposite side of the injection.

18. **A** The vena retromandibularis runs through the parotid space.

    B, C The arteria carotis interna and the vena jugularis interna travel medial to the parotid space.
    D The arteria masseterica branches from the arteria maxillaris medial and internal to the parotid space.
    E The arteria buccalis branches from the arteria maxillaris medial and internal to the parotid space.

19. **B** If the injection was too far posterior and inferior, there would be penetration into the parotid space with probable anesthesia of branches of the nervus facialis. There would be no anesthesia of the nervus alveolaris inferior, as evidenced by failure to numb the lower lip (no lower lip sign).

    A, C, E If the injection was too far superior and anterior, too far anterior and inferior, or too far medial and superior, there would only be anesthesia at the injection site and no anesthesia of the nervus alveolaris inferior, as evidenced by failure to numb the lower lip (no lower lip sign). There also would be no penetration into the parotid space.
    D If the injection was too far medial and inferior, there would be possible anesthesia of the nervus lingualis. More likely, there would only be anesthesia at the injection site and no anesthesia of the nervus alveolaris inferior, as evidenced by failure to numb the lower lip (no lower lip sign). There also would be no penetration into the parotid space.

20. **C** There are sensory fibers that sometimes travel on the nervus mylohyoideus. These sensory fibers may provide innervation to the dentes mandibulares.

    A The nervus lingualis carries sensory fibers to the anterior two-thirds of the tongue and the lingual gingiva of the dentes molares mandibulares, but not to the teeth themselves.
    B The nervus buccalis provides sensory fibers to the mucosa and skin of the cheek and to the buccal gingiva of the dentes molares mandibulares, but not to the teeth themselves.
    D The ramus marginalis mandibularis is a motor branch of the nervus facialis.
    E The rami buccales of CN VII are motor branches of the nervus facialis.

21. **B** Trigeminal neuralgia affects the branches of the nervus trigeminus, typically in the following order: $V_2 > V_3 > V_1$. More often than not, it only affects the nervus maxillaris and nervus mandibularis and their branches. As described in this scenario, it is affecting branches of the nervus mandibularis, with the associated pattern of pain.

    A Bell palsy affects the nervus facialis and the musculi faciei, not the musculi masticatorii.
    C Geniculate neuralgia involves similar pain patterns as trigeminal neuralgia but deals with the pain areas of the nervus facialis, not the trigeminalus. This may include pain associated with the meatus acusticus externus or even pain felt deep within the ear. It is sometimes associated with herpes zoster and can result in vesicular eruptions on the eardrum and porus acusticus externus.
    D Glossopharyngeal neuralgia involves similar pain patterns as trigeminal neuralgia but deals with the pain areas of the nervus glossopharyngeus, not the trigeminalus. This may include pain associated with the tongue, pharynx, throat, ear, and tonsils.
    E Temporal arteritis is pain associated with areas overlying, or adjacent to, the arteria temporalis superficialis, although it can be other arteries in the head. Severe headaches can result from temporal arteritis.

22. **B** The areas of pain associated with the scenario include regions of the nervus alveolaris inferior (the mandibula, skin over the mandibula, and skin over the inferior aspect of the fossa infratemporalis, as well as a portion of the internal aspect of the mouth) and the nervus lingualis (mucosa of the anterior two-thirds of the tongue and a portion of the internal aspect of the mouth).

    A Pain associated with the nervus trigeminus would be all of the pain domains of the nervi ophthalmicus, maxillaris, and mandibular branches, which include the entire side of the face from the upper frontal regions down to the neck. This is not what occurred in the scenario.
    C The sensory distribution areas of the nervus maxillaris are the more superior aspect of the fossa infratemporalis, the skin overlying the maxilla and a portion of the nasal area, the dentes maxillares, and the mucosa and gingiva of the maxillary region. Pain was not described in these regions.
    D Areas of pain associated with the nervus alveolaris inferior were reported, but pain associated with areas of the lingual nerve was also reported.
    E Areas of pain associated with the nervus lingualis were reported, but pain associated with areas of the nervus alveolaris inferior was also reported.

23. **C** The musculus temporalis is one of the major elevators of the mandibula. The other two are the musculus masseter and musculus pterygoideus medialis.

    A The musculus buccinator is a muscle of facial expression and does not move the mandibula.
    B Actions of the musculus pterygoideus lateralis include protrusion, depression, and medial excursion of the mandibula. The caput superius of the musculus pterygoideus lateralis also stabilizes the condylus mandibulae during retrusion. The musculus pterygoideus lateralis does not function in elevation of the mandibula.

D, E The musculus mylohyoideus and venter anterior musculi digastrici play a role in depression of the mandibula.

24. **B** The ganglion trigeminale, would be ablated in this procedure.

A The ganglion geniculi is associated with the nervus facialis (CN VII). As previously stated, the nervus facialis would not be involved in this syndrome.
C The ganglion inferius (not superius) of CN IX is the general sensory ganglion of the nervus glossopharyngeus and thus would not be involved with pain patterns associated with the nervus trigeminus (CN V).
D The ganglion pterygopalatinum is one of the parasympathetic motor ganglia of the head. It is associated with the nervus facialis.
E The ganglion superius of CN X is the general sensory ganglion of the nervus vagus and thus would not be involved with pain patterns associated with the nervus trigeminus.

25. **D** Bell palsy involves dysfunction of the nervus facialis. This is normally of unknown etiology. It can involve all of the functions associated with the nervus facialis but most often involves only ipsilateral paralysis of all of the musculi faciei.

A A left-sided cerebral stroke produces paralysis of all of the muscles of the right side of the body, not just the face.
B A right-sided cerebral stroke produces paralysis of all of the muscles on the left side of the body, not just the face.
C, E Trigeminal neuralgia and glossopharyngeal neuralgia produce tremendous pain, but not muscle paralysis.

26. **A** As initially stated, the symptoms involve only the musculi faciei. This is consistent with damage to the nervus facialis at a spot where only branchial efferent impulses are carried. This spot is either just proximal to or within the glandula parotidea.

B There are motor fibers of the nervus facialis that supply the musculus occipitalis and small muscles of the skin around the ear (auriculares). These muscles would be affected if the damage to the facial nerve was just distal to its exit from the foramen stylomastoideum. In addition, the musculus stylohyoideus and venter posterior musculi digastrici would be denervated.
C The same caveat as for answer choice B applies for this answer. In addition, depending on where the compression occurred, there may be disruption of sensory impulses to the ramus auricularis or nervus auricularis posterior of CN VII.
D If the compression was just proximal to the branching of the chorda tympani, not only would all of the aforementioned symptoms occur, but symptoms involving the chorda tympani would also be witnessed. These include difficulties with taste and a possible perception of lessened salivation.
E If the compression was just distal to the branching of the chorda tympani, the symptoms would be the same as described in answer choice C.

27. **C** If the compression was just proximal to the point at which the nervus petrosus major branches, the symptoms would include ipsilateral paralysis of the musculi faciei and the musculus occipitalis and small muscles of the auris externa. In addition, the musculus stylohyoideus and venter posterior musculi digastrici would also be denervated. Symptoms would include a lack of sensation associated with the ramus auricularis of CN VII, diminished taste, and a possible perception of lessened salivation. Functions associated with the nervus petrosus major would be disrupted, including loss of parasympathetic output from the ganglion pterygopalatinum to glandulae in the cavitas nasi, pharynx, and mucosa of the palatum, as well as to the glandula lacrimalis, resulting in lack of lacrimation. In addition, there would be lack of taste from scattered caliculi gustatorii on the palatum molle, although this would be barely perceptible by the patient. Finally, there might be a perception of increased "noise" on the side of the injury due to lack of function of the nervus stapedius.

A Only the musculi faciei, ipsilateral to the damage, would be affected as a result of compression of the nervus facialis as it travels through the glandula parotidea.
B If the compression was just proximal to the branching of the chorda tympani, the symptoms would include ipsilateral paralysis of the musculi faciei, the musculus occipitalis, and small muscles of the auris externa. In addition, the musculus stylohyoideus and venter posterior musculi digastrici would be denervated. Symptoms would include a lack of sensation associated with the ramus auricularis of CN VII, diminished taste, and a possible perception of lessened salivation.
D The symptoms would include all those stated in answer choice B if the compression was just distal to where the nervus petrosus major branches. In addition, there might be a perception of increased "noise" on the side of the injury due to a lack of function of the nervus stapedius.
E If the compression was just distal to the point at which the chorda tympani branches, symptoms would include ipsilateral paralysis of the musculi faciei, ipsilateral paralysis of the small muscles of the auris externa and musculus occipitalis, denervation of the musculus stylohyoideus and venter posterior musculi digastrici, and loss of sensation associated with the ramus auricularis of CN VII.

28. **D** The musculus levator palpebrae superioris is innervated by the oculomotor nerve and acts in elevating the eyelid. It is unopposed in facial nerve (CN VII) paralysis, causing the eyelid to be abnormally elevated.

A, B The orbicularis oculi is innervated by the zygomatic and temporal branches of CN VII. However, these nerves act to depress the eyelid, not elevate it.
C The levator palpebrae superioris does elevate the eyelid. However, it is innervated by a branch of the oculomotor nerve, not the temporal branch of CN VII.
E The corrugator supercilii and frontalis are innervated by branches of the temporal branch of CN VII. However, neither acts to elevate the eyelid.

29. **C** Fibers of the left nervus laryngeus recurrens supply the majority of intrinsic muscles of the larynx. They also supply the mucosa of the larynx from the plicae vocales and below. It is this nerve that would be constricted as it loops around the arcus aortae.

A Symptoms due to damage to the nervus vagus, depending on the location of the damage, would include those described for all of the nerves listed in the question. In addition, there might be changes in heart rate and in muscle tone associated with the gastrointestinal tract.
B Fibers from the ramus externus nervi laryngei superioris innervate only the musculus cricothyroideus of the larynx and sometimes the pars cricopharyngea musculi constrictoris pharyngis inferioris. The symptoms described above would not result from compression of this nerve, nor does it loop around the aorta.
D The rami externus and internaus are branches of the nervus laryngeus superior. The function of the ramus externus has already been described.
E The ramus internus nervi laryngei superioris supplies sensory fibers to the mucosa of the larynx above the plicae vocales. This might produce some of the same symptoms; however, because the nerve does not loop around the aorta, it would not be constricted in this scenario.

30. **C** Maxillary sinusitis can be interpreted as pain associated with the maxillary molars. In many patients, this pain is exacerbated because of allergies associated with flowering plants in the spring and rotting leaves in the fall.

A Pain associated with trigeminal neuralgia is episodic and extreme. It also does not occur on a seasonal basis.
B, D, E Masseteric spasms, auris media infection, and temporomandibular dysfunction can be interpreted as pain associated with the maxillary molars. However, the pain would not occur on a seasonal basis.

31. **C** Sensory impulses to the cerebrum are relayed through the thalamus. The thalamus is involved in localizing sensory impulses to areas in the body.

A The colliculus superior is involved with sight and the coordination of the muscles that move the eyeballs.
B The colliculus inferior is involved with hearing.
D The hypothalamus, among other things, is involved with hunger, thirst, memory, and sexuality. It is not involved with the localization of sensory impulses.

E The globus pallidus is part of the basal ganglia. Its primary function is modulation of motor impulses.

32. **A** Perception of pain, along with perception of most other sensations, is associated with the gyrus postcentralis of the lobus parietalis.

    B Initiation of motor impulses is associated with the gyrus precentralis of the lobus frontalis.
    C The gyrus temporalis superior is associated with hearing, both perception and memory.
    D The gyrus lingualis of the lobus occipitalis is involved with sight.
    E The gyrus cinguli is involved with memory, primarily long-term retrograde.

33. **B** The musculus pterygoideus medialis inserts on the internal aspect of the angulus mandibulae, and the musculus masseter inserts on the external aspect of the angulus mandibulae. These two form the pterygomasseteric sling.

    A The musculus pterygoideus medialis inserts on the internal aspect of the angulus mandibulae; the musculus pterygoideus lateralis inserts onto the condylus mandibulae, the meniscus, and the fovea pterygoidea of the mandibula.
    C The musculus masseter inserts on the external aspect of the angulus mandibulae; the musculus temporalis inserts on the processus coronoideus of the mandibula and the internal aspect of the superior portion of the ramus mandibulae.
    D, E The insertions of the musculi temporalis, pterygoideus medialis, and pterygoideus lateralis have already been described.

34. **A** The musculi masticatorii, venter anterior musculi digastrici, musculi myohyoideus, tensor tympani, and tensor veli palatini develop from the arcus pharyngeus primus.

    B The musculi faciei, musculus occipitalis, musculi auriculares, venter posterior musculi digastrici, musculus stylohyoideus, and musculus stapedius develop from the arcus pharyngeus secundus.
    C The musculus stylopharyngeus develops from the arcus pharyngeus tertius.
    D Muscles of the palatum molle, pharynx, and larynx develop from the arcus pharyngeus quartus.
    E The arcus pharyngeus quintus degenerates; nothing develops from it.

35. **E** The ameloblastoma develops within the mandibula. It can break out from the mandibula, but it would first affect nerves that travel through the mandibula, and the only nerve listed that fulfills that criterion is the nervus alveolaris inferior. The nervus alveolaris inferior originates in the fossa infratemporalis and travels through the foramen mandibulae to gain access to the internal aspect of the mandibula.

    A The nervus buccalis runs on the lateral aspect of the maxilla down to the external aspect of the mandibula and the gingiva of the internal aspect of the mandibula.
    B The nervus lingualis originates in the fossa infratemporalis and enters into the cavitas oris deep to the musculi mylohyoideus and hyoglossus.
    C The nervi temporales profundi originate in the fossa infratemporalis and travel to the fossa temporalis to innervate the musculus temporalis.
    D The nervus pterygoideus lateralis originates in the fossa infratemporalis and terminates in the deep aspect of the two heads of the musculus pterygoideus lateralis.

36. **C** The chorda tympani carries taste fibers from the nervus facialis. These taste fibers then travel from the chorda tympani to the nervus lingualis.

    A Taste does hitchhike in the nervus lingualis branch of the nervus trigeminus to the anterior two-thirds of the tongue, but not initially.
    B The nervus alveolaris inferior branch of the nervus trigeminus carries branchial efferent fibers and general sensory fibers, not taste fibers.
    D The nervus petrosus major branch of the nervus facialis carries parasympathetic and taste fibers. However, the taste fibers go to scattered caliculi gustatorii associated with the palatum molle, not the tongue. Also, there are so few caliculi gustatorii associated with these fibers, that their dysfunction would be barely noticeable.
    E The nervus petrosus minor branch of the nervus glossopharyngeus carries preganglionic parasympathetic fibers that synapse in the ganglion oticum.

37. **C** The majority of caliculi gustatorii are found on the papillae vallatae.

    A There are no caliculi gustatorii on papillae filiformes.
    B There are a minimal number of caliculi gustatorii on papillae fungiformes.
    D There are a few scattered caliculi gustatorii associated with the papillae foliatae.
    E Caliculi gustatorii are primarily associated with the papillae vallatae.

38. **D** The nervi petrosi major and minor both contain fibers that stimulate salivation (therefore not A or B alone). The nervus petrosus major carries preganglionic parasympathetic fibers from the nervus facialis that synapse in the ganglion pterygopalatinum. Some postganglionic parasympathetic fibers travel to scattered glandulae salivariae in the mucosa of the palatum molle. The nervus petrosus minor carries preganglionic parasympathetic fibers from the nervus glossopharyngeus that synapse in the ganglion oticum. Postganglionic parasympathetic fibers travel in the nervus auriculotemporalis to the glandula parotidea.

    C The nervus petrosus major carries postganglionic sympathetic fibers that originate in the ganglion cervicale superius. These fibers are not involved with stimulation of salivation. Salivation is predominantly under parasympathetic control but sympathetic stimulation may result in a small flow of saliva that is rich in protein.
    E Incorrect.

39. **D** Preganglionic parasympathetic fibers originate in the nervus facialis, travel to the chorda tympani, and synapse in the ganglion submandibulare. Postganglionic fibers travel to the glandulae submandibularis and sublingualis and small salivary groups found in the tongue and oral mucosa.

    A The ganglion ciliare is a parasympathetic ganglion associated with the nervus oculomotorius (CN III). Postganglionic fibers from the ganglion carry impulses that cause constriction of the pupilla as they innervate the musculus sphincter pupillae and accommodation via musculus ciliaris contraction.
    B The ganglion cervicale superius is a sympathetic ganglion that provides postganglionic fibers for the head and neck.
    C The ganglion cervicale medium is a sympathetic ganglion that provides postganglionic fibers to the heart and glandula thyroidea.
    E Preganglionic parasympathetic fibers originate in the nervus facialis, travel to the nervus petrosus major and the nervus canalis pterygoidei, then synapse in the ganglion pterygopalatinum. Postganglionic fibers go to very minor glandulae salivariae found in the palatum molle and mucosa of the cavitas oris. They also travel to the glandula lacrimalis.

40. **E** In Ludwig angina, infection is found bilaterally in the submandibular and sublingual spaces and in the submental space.

    A–D In Ludwig angina, infection is found in these spaces, but not exclusively.

41. **C** Ludwig angina results from an infection of a radix dentis that impinges into either the submandibular or the sublingual space; therefore, it can emanate from any of the dentes mandibulares.

    A The inferior aspects of the dentes molares mandibulares are found in the submandibular space, but they do not exclusively lead to Ludwig angina.
    B The inferior aspects of the radices of the dentes incisivi and canini mandibulares are found in the sublingual space, but they do not exclusively lead to Ludwig angina.
    D, E Radices of the dentes maxillares do not gain access to the submandibular or sublingual spaces.

42. **A** Because the most superior structure is the ductus submandibularis, it will be encountered first.

    B The nervus lingualis is found just inferior to the ductus submandibularis.
    C The arteria lingualis is the most inferior of the structures listed.
    D The nervus hypoglossus runs between the nervus lingualis and the arteria lingualis.

E The nervus glossopharyngeus is not found in the floor of the cavitas oris. It enters the tongue on its posterior aspect.

43. **B** The arteria facialis runs through the glandula submandibularis.

A The vena facialis runs superficial to the glandula submandibularis.
C The arteria lingualis runs deep to the glandula submandibularis.
D The nervus hypoglossus runs deep to the glandula submandibularis.
E The anterior division of the vena retromandibularis runs superior to the glandula submandibularis.

44. **B** The ramus marginalis mandibularis of the nervus facialis runs on the superficial surface of the glandula submandibularis.

A The ramus cervicalis of the nervus facialis runs posterior to the glandula submandibularis.
C The nervus mentalis branch of the nervus trigeminus runs on the anteromedial surface of the mandibula and is superior and anterior to the glandula submandibularis.
D The fibers of the nervus buccalis branch of the nervus trigeminus run on the superficial aspect of the cheek and into the gingiva of the mandibula, not onto the glandula submandibularis.
E The inferior fibers of the rami buccales of the nervus facialis travel on the lateral aspect of the cheek and are superior to the glandula submandibularis.

45. **E** The glandula submandibularis sits on the anterior surface of the musculus mylohyoideus, and a portion of the posterior aspect of the gland, as well as the ductus submandibularis, wraps around the muscle to its inferior aspect.

A The musculus hyoglossus is deep to both the glandula submandibularis and the musculus mylohyoideus.
B The venter anterior musculi digastrici is the anterior border of the trigonum submandibulare, and the glandula submandibularis sits within the triangle. The glandula submandibularis is posterior, and superficial, to much of the venter anterior. It does not wrap around it.
C The venter posterior musculi digastrici is the posterior border of the trigonum submandibulare. The glandula submandibularis sits anterior to the venter posterior musculi digastrici.
D The musculus genioglossus essentially sits within the cavitas oris and is deep to the trigonum submandibulare. It is also anterior to the glandula submandibularis.

46. **E** The alar layer of the lamina prevertebralis fasciae cervicalis is the border between the danger space and the spatium retropharyngeum.

A The posterior layer of the lamina prevertebralis fasciae cervicalis is the posterior border of the danger space.
B The lamina pretrachealis fasciae cervicalis is the anterior border of the spatium retropharyngeum.
C In this case, the fascia buccopharyngealis is synonymous with the lamina pretrachealis fasciae cervicalis; that is, they are continuous.
D The medial aspect of the vagina carotica is the lateral border of the spatium retropharyngeum.

47. **C** Infections from the spatium retropharyngeum and/or danger space travel into the mediastinum and can then spread to the heart, resulting in pericarditis (inflammation of the pericardium [outer layer] of the heart).

A Infections from the radices dentum maxillarium, cavitas nasi, or orbita may travel into the sinus maxillaris with a resulting sinus maxillaris infection.
B Infections from the periorbital and infraorbital space, the supraorbital area, and the veins of the face, specifically, the plexus pterygoideus, may travel into the sinus cavernosus. This can result in a sinus cavernosus infection and/or thrombosis, which can be fatal in a matter of days.
D Infections from the head normally do not gain access to the cavitas peritonealis.
E Infections from the supraorbital and infraorbital areas, as well as the cavitas nasi and sinus maxillaris, can gain access to the orbit. Symptoms associated with infections in the orbita include exophthalmos (bulging eyes) and diplopia (double vision).

48. **E** The glandula thyroidea is an endocrine gland and secretes into veins that are located on its lateral aspect. A vertical midline incision does not harm these vessels.

A The thymus regresses as we age, not the glandula thyroidea.
B, C The glandula thyroidea is an endocrine not an exocrine, gland.
D The glandula thyroidea does not secrete angiogenic factors. Vessels cannot grow back to the glandula thyroidea once they are severed.

49. **D** The consensual light reflex occurs when a light is shined in one pupilla, resulting in both pupils constricting.

A The corneal reflex involves brushing the cornea and watching for the eyelid to shut.
B The pupillary dilator reflex is an involuntary reflex involving dilation of the pupilla.
C The vestibulo-ocular reflex occurs when the head is moved, but the image viewed remains in a constant point on the retina.
E The accommodation reflex is the adjustment of the shape of the lens to keep objects in focus when focal lengths change. This was not being tested.

50. **A** The corpus geniculatum mediale is involved with hearing. It is part of the auditory pathway. Fibers from the colliculus inferior travel to, and synapse in, the corpus geniculatum mediale. Fibers from the corpus geniculatum mediale travel to the auditory cortex of the lobus temporalis. It is therefore not involved in the consensual light reflex.

B–E In the consensual light reflex, sensory impulses from the retina travel to the nuclei pretectales via the nervus opticus (E). Fibers from the nuclei pretectales communicate with each other via the commissura posterior (D). Fibers from the nuclei pretectales travel to the nuclei viscerales nervi oculomotorii. Preganglionic fibers from the Edinger–Westphal (C) travel to the ganglion ciliare (B). Postganglionic fibers from the ganglion ciliare travel to the musculus sphincter pupillae and cause the pupilla to constrict.

51. **B** The arteria meningea media is found in the spatium epidurale. A sudden tear of the artery would enlarge the spatium and potentially compress structures found on the dorsal aspect of the midbrain, including the nuclei pretectales and commissura posterior. This could result in disruption of the consensual light reflex.

A A tear of the lining of a ventriculus could cause leakage of liquor cerebrospinalis (CSF). However, this could not be tested through the consensual light reflex. A small tear of the ventriculus would gradually leak CSF, but under most circumstances, there is no way to directly test for this.
C Venae meningeae and cerebri are found in the spatium subdurale; in some rare cases, when they rip, pooling of blood can compress neuronal structures. However, in most cases, these tears result in a slow bleed that is not detected for a matter of hours or days, whereas the testing was to determine if a neuronal difficulty had occurred immediately. Testing for tears of these veins would only occur after symptoms, such as dizziness or semiconsciousness, had manifested themselves. The testing would involve CT scans or MRI with contrast.
D, E An occlusion of an arteria cerebri would not be tested via the consensual light reflex. An angiography of the cerebral vessels would determine if this occlusion occurred.

52. **B** The nervus accessorius can be damaged in a radical neck dissection. The nervus accessorius innervates the musculus sternocleidomastoideus, which participates in rotation of the head. It also innervates the musculus trapezius, which participates in elevation of the shoulder (scapula).

A Idiopathic spasmodic torticollis is normally inherited and not due to acute damage to a nerve.
C The nervus vagus lies in the vagina carotica and is normally not damaged in a radical neck dissection.
D Branches of the ansa cervicalis could be injured in a radical neck dissection, but the muscles it innervates (venter inferior musculi omohyoidei, venter superior musculi omohyoidei, musculus sternohyoideus, and musculus sternothyroideus) are not involved in rotation of the head.

E The nervus phrenicus could conceivably be damaged in a radical neck dissection; however, it does not innervate muscles involved with rotation of the head, but rather innervates the diaphragm.

53. **C** The nervus hypoglossus (CN XII) innervates all of the intrinsic muscles of the tongue and all extrinsic muscles of the tongue (musculi genioglossus, hyoglossus, and styloglossus) except the musculus palatoglossus, which is innervated by the nervus vagus (CN X).

A The nervus alveolaris inferior supplies sensory fibers to the dentes mandibulares and the skin overlying a portion of the mandibula.
B The chorda tympani carries preganglionic parasympathetic fibers and taste fibers.
D The nervus mandibularis branch of the nervus trigeminus supplies sensory fibers to the majority of the head and motor fibers to the musculi masticatorii, the musculus mylohyoideus, the venter anterior musculi digastrici, the musculus tensor tympani, and the musculus tensor veli palatini.
E The nervus glossopharyngeus supplies taste to the posterior one-third of the tongue, sensory from the upper portion of the pharynx, general sensory to the posterior one-third of the tongue, sensory from the meatus acustica externa, and motor to the musculus stylopharyngeus. It does not supply muscles of the tongue.

54. **C** Damage to the right nervus hypoglossus results in the right musculus genioglossus not working properly. The right musculus genioglossus protrudes the tongue toward the left. Thus, the left musculus genioglossus would work unopposed, and the tongue, upon protrusion, deviates to the right. That is what is demonstrated in the photo.

A, B The musculus hyoglossus depresses and retrudes the tongue. Protrusion is demonstrated in the photo.
B, D Damage to the left musculus genioglossus results in the tongue deviating toward the left.
E Damage to the left nervus genioglossus results in the tongue deviating toward the left. Damage to the left musculus hyoglossus results in difficulties with depressing and retruding the tongue.

55. **D** The nodi infraclaviculares are not part of the axillary group of nodi lymphoideae. Lymph from the axillary group drains to the nodi infraclaviculares and nodi supraclaviculares.

A The nodi pectorales are part of the axillary group of nodes. Lymph from the anterior chest wall and glandula mammaria drains to the nodi pectorales.
B The nodi laterales are part of the axillary group of nodes. Lymph from the upper limb drains to the nodi laterales.
C The nodi subscapulares are part of the axillary group of nodes. Lymph from the neck, back, and posterior aspect of the thoracic wall drains to the nodi subscapulares.
E The nodi apicales are part of the axillary group of nodes. Lymph from the nodi laterales drains to the nodi apicales.

56. **C** Medial rotation of the humerus is accomplished through the actions of the musculi pectoralis major, teres major, latissimus dorsi, and subscapularis.

A Inferior rotation of the scapula is accomplished through the actions of the musculi rhomboideus major, rhomboideus minor, levator scapulae, and pectoralis minor.
B Superior rotation of the scapula is accomplished through the actions of the musculi trapezius and serratus anterior.
D Abduction of the humerus is accomplished through the action of the medial fibers of the musculi deltoideus, supraspinatus and serratus anterior.
E Extension of the humerus is accomplished through the actions of the musculus latissimus dorsi and posterior fibers of the musculus deltoideus.

57. **A** The nervus thoracicus longus is found on the lateral chest wall. A portion of it is found within the confines of the axilla. As the nervus thoracicus longus travels on the superficial aspect of the musculus serratus anterior, fibers from the nerve gain access to individual parts of the muscle. Because of its placement on the superficial aspect of the muscle, it is sometimes damaged as lymph and adipose tissue are removed during a radical mastectomy.

B The nervus pectoralis medialis innervates the musculus pectoralis minor, but fibers from the nerve enter it from its deep aspect. The nerve then travels to the deep surface of the musculus pectoralis major, which it also innervates.
C The nervus pectoralis lateralis innervates the musculus pectoralis major. It gains access to the muscle from its deep aspect.
D The nervus thoracodorsalis innervates the musculus latissimus dorsi and gains access to it from its deep aspect.
E The nervus axillaris innervates the musculi deltoideus and teres minor. In both cases, as it travels through the quadrangular space, it gains access to the deep aspects of the muscles.

58. **A** The musculus rhomboideus major participates in retraction, elevation, and inferior rotation of the scapulae.

B The musculus teres major participates in medial rotation, extension, and adduction of the humerus.
C The musculus teres minor participates in lateral rotation of the humerus.
D The musculus latissimus dorsi participates in medial rotation, extension, and adduction of the humerus.
E The musculus longissimus participates in extension and stabilization of the columna vertebralis.

59. **C** The ramus nodi sinuatrialis is a branch of the arteria coronaria dextra.

A The arteria coronaria sinistra branches at the most proximal portion of the pars ascendens aortae.
B The ramus interventricularis anterior is a branch of the arteria coronaria sinistra.
D The ramus interventricularis posterior is a branch of the arteria coronaria dextra.
E The ramus marginalis dexter branches from the arteria coronaria dextra.

60. **E** Referred pain from the heart is normally not referred to the right hypogastrium. Some of the structures found in the right hypogastrium are the caecum, appendix vermiformis, and colon ascendens.

A–D Pain associated with angina is classically referred to the left shoulder and left upper limb (A). It can also be referred to the posterior shoulder and back, although the pain associated with aortic dissection is more commonly felt in the back between the shoulder blades. (B), to the midline of the mandibula (C), and to the anterior aspect of the neck (D).

61. **E** Referred pain from the oesophagus, as in oesophagitis or gastric reflux, can be referred to the midsternal region (A), as can pain from the stomach (B) and the pancreas, as in pancreatitis or pancreatic cancer (C).

D Not applicable.

62. **C** The pericardial space (or cavity), with pericardial fluid, is found between the lamina parietalis of the pericardium serosum and the lamina visceralis of the pericardium serosum. Fluid is drained from the pericardial space by needle aspiration in a procedure known as pericardiocentesis.

A The pericardial fat lies on the superficial aspect of the pericardium fibrosum. There is no discernible space between the two layers.
B There is a small bit of nonspecific lymphatic-type fluid between the lamina parietalis of the pericardium serosum and pericardium fibrosum, but there is no discernible space.
D The lamina visceralis of the pericardium serosum is superficial to the myocardium; there is no potential, or actual, space between them.
E The myocardium is superficial to the endocardium; there is no potential, or actual, space between them.

63. **E** The nervus medianus is found in the forearm and runs deep to the retinaculum musculorum flexorum of the wrist and travels through the canalis carpi.

A The ramus profundus nervi radialis is found in the compartimentum antebrachii posterius.
B The ramus superficialis nervi radialis is found in the superficial fascia of the compartimentum antebrachii posterius.

C The nervus cutaneus antebrachii lateralis is found in the superficial fascia of the anterolateral aspect of the forearm.
D The nervus ulnaris is found in the proximal portion of the compartimentum antebrachii anterius but is superficial to the investing fascia in the distal portion of the forearm and superficial to the retinaculum musculorum flexorum of the wrist. The nervus ulnaris does not run through the canalis carpi.

64. **B** The musculus flexor pollicis brevis is innervated by the recurrent branch of the nervus medianus. If the nervus medianus was compressed in the distal aspect of the forearm or in the canalis carpi, the recurrent branch would be dysfunctional.

A, C, D The musculi flexor pollicis longus, flexor digitorum superficialis, and flexor carpi radialis are innervated by the nervus medianus, but the nerve enters into these muscles in the proximal portion of the forearm and thus should not be affected in the scenario presented.
E Not applicable.

65. **A** Fine motor movements of the thumb are achieved through the action of the musculi flexor pollicis brevis, abductor pollicis brevis, and opponens brevis. All of these muscles are innervated by the recurrent branch of the nervus medianus, which may be affected in anterior compartment syndrome.

B Adduction of the thumb is via the musculus adductor pollicis, which is innervated by the nervus ulnaris.
C Flexion of the fingers is accomplished via the musculus flexor digitorum superficialis, which is innervated by the nervus medianus, but the nervus medianus enters the muscle proximal to where the blood would pool. The musculus flexor digitorum profundus is innervated by the nervus medianus (same caveat applies) and the nervus ulnaris.
D Extension at the articulationes carpometacarpales is accomplished through the action of the musculi extensor digitorum and extensor indicis. Both muscles are innervated by the nervus radialis.
E Not applicable.

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